PRODUCTION AND VALUE

OF

MINERAL PRODUCTS IN MICHIGAN

FOR

1915 AND PRIOR YEARS

AND

A REPORT ON MICHIGAN LIMESTONES

MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY

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MINERAL RESOURCES OF MICHIGAN

WITH

STATISTICAL TABLES OF PRODUCTION AND VALUE OF MINERAL PRODUCTS

FOR

1915 AND PRIOR YEARS.

WITH A TREATISE ON LIMESTONE RESOURCES

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LETTER OF TRANSMITTAL.

To the Honorable, the Board of Geological and Biological Survey of the State of Michigan:

Gov. Woodbridge N. Ferris.
Hon. Thomas W. Nadal.
Hon. Fred L. Keeler.

Gentlemen:—Under authority of act number seven, Public Acts of Michigan, Session of 1911, I have the honor to present herewith Publication 21, Geological Series 17, the fifth of a series of annual statements of the production and value of the mineral products of Michigan, with a special article by R. A. Smith on Limestone Resources.

Very respectfully,

R. C. ALLEN,
Director.

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PART I. METALLIC MINERALS.

THE MICHIGAN COPPER INDUSTRY IN 1915.

WALTER E. HOPPER.

GENERAL REVIEW.

The production of the Michigan copper mines during the year 1915 was the largest in the history of the industry. According to the figures of the U. S. Geological Survey, the total refined copper produced amounted to 238,956,410 pounds, as compared with 158,009,748 pounds in 1914 and with 231,112,228 pounds in 1912, the record production previous to 1915.

There was mined and milled in the Lake Superior district 12,334,699 tons of ore-producing concentrates, containing 265,283,378 pounds of copper, or a recovery of slightly above one per cent of copper from the ore. A portion of the concentrates produced was not smelted in 1915.

At an average price of 17.5 cents per pound, the copper output of Michigan in 1915 had a value of about $41,800,000. The copper mines also produced in 1915, 585,933 ounces of silver, valued at $297,068.

At the beginning of the year practically all development and exploratory work was in a state of suspension and all the producing mines, with the exception of the Mohawk and Wolverine, were operating on a reduced scale of production and wages. The conditions at the close of the year were in marked contrast to those at the beginning of the year. At the close of 1915 all producing mines were increasing production as rapidly as possible and practically all non-producing mines were again in operation. The large increase in total production and the renewed activity in development and exploratory work were due directly to the large consumption and to the high price received for copper sold.

Among the notable achievements of the year may be mentioned the remarkable increase in yield of refined copper per ton of ore stamped and the decided lowering of the cost per pound of copper produced. Both of these are due to various improvements in mining practice, the introduction of new mining and milling machinery and especially to a closer selection and better sorting of ore underground.

The one-man drill and the Carr bit have doubled the output per miner of a few years ago. A close study of the breaking of ore underground and the introduction of lighter and more efficient drilling machines have resulted during the last five years in a saving of over $2,000,000 to the mining companies, and, at the same time, the workmen have benefited by over $1,000,000.

The use of the low-pressure steam turbine has increased and Ahmeek,

Champion and Isle Royale installed this equipment during 1915. Regrinding is now done at many of the mills and steel balls have replaced the flint pebbles in the Hardinge mills. The Calumet & Hecla began the treatment of tailings from its large pile of over 35,000,000 tons of stamp sand and results have been excellent. A large recovery of copper is being made at a very low cost. The leaching plant now in the process of construction will probably be in operation before the close of 1916. At the Copper Range mines the use of waste stamp sand for filling stopes has been increased. This sand fill makes possible a more complete extraction and thorough exploration of the lode.

With improved conditions in the copper market wages were increased until they are now the highest ever known in the district. The managements felt that the employees, because of their loyalty and efficiency, should share in the existing prosperity due to the higher price of copper. The employees of the Calumet & Hecla and its subsidiaries received as a premium the wages forfeited under the reduced rate of pay from September 1, 1914 to May 1, 1915. Contract work and bonus systems make it possible for the efficient men underground to earn almost double the basic rate. On May 1 wages at the Quincy mine were restored to the basis existing prior to September 1914, which was the highest rate ever paid employees, but with the advance in the price of copper, wages were increased about seven and one-half per cent December 1, and another advance of seven and one-half per cent will take effect March 1, 1916, making 15 per cent in all.

EXPLORATION AND DEVELOPMENT WORK.

The great demand and high price for copper stimulated interest in exploration and development work during 1915.

The Houghton Copper Company, the South Lake and the New Arcadian sent ore to the mills during 1915. The White Pine has been a steady producer on a limited scale since April. All of these are new producers.

At the northern end of the district Keweenaw continued exploration of the Ashbed lode on the Phoenix property, and a mill test will be made during the summer of 1916.

On the Cliff lands in Keweenaw county seven diamond drill holes were put down to explore the Ashbed lode, the Calumet conglomerate and the Osceola amygdaloid.

Mayflower and Old Colony continued their exploration of the Mayflower lode by diamond drilling and the latter will soon be in a position to start a shaft to develop the mineral deposit which has been so persistent in each hole drilled.

Algomah resumed exploration work in April. The mine was unwatered and sinking of the shaft resumed in June. The shaft is sinking towards the point where the Lake, South Lake and Algomah properties join.

Diamond drilling at the Contact was successful in locating in two holes the Wyandot No. 8 lode. Where cut, the lode possesses all the favorable characteristics of other commercially mineralized beds of the district.

Cherokee resumed exploration work during the summer of 1915. Numerous cross-trenches and pits revealed an amygdaloid lode, showing such promising mineralization, as to warrant the installation of a plant sufficient to sink an exploring shaft to a depth of 500 to 700 feet. This work will probably commence in the spring of 1916.

Indiana carried on an unsuccessful search on the 600 foot level for No. 2 drill hole, which showed a rich deposit of copper. Drifting in search of the deposit is now under way at the 1,150 and 1,400 foot levels.

Naumkeag continued exploratory work and the results show that there is a shoot of copper bearing ground in the northern part of the property which undoubtedly is worthy of development in depth.

North Lake operated continuously throughout the year. Three very promising looking amygdaloid lodes, all carrying copper, were exposed. These probably correspond to the South Lake lodes Nos. 1, 2 and 3. The shaft is now being sunk to the 800 foot level.

New Arcadian continued development work on the New Arcadian lode, and also found No. 8 conglomerate to be well mineralized on the 900 foot level. Results were very encouraging.

Exploratory work at the New Baltic consisted of trenching and diamond drilling for the purpose of definitely locating the outcrop of the New Arcadian lode and No. 8 conglomerate. The results of the diamond drill work were very favorable.

Onondaga resumed exploration of its lands within the Nonesuch basin. A series of drill holes finally located the Nonesuch lode, and further work will consist of drilling to find some mineralized portion of the lode on the company's lands.

The most extensive and perhaps the most interesting exploratory work of the year was done in the Porcupine Mountain district, Ontonagon county. The White Pine Extension was organized in July to explore and develop lands west of the White Pine and Nonesuch mines. An extensive diamond drilling campaign was begun in the spring of the year and results were so encouraging that a shaft is now being sunk to develop a large area of the Nonesuch formation.

The Michigan resumed operations in July after a suspension of all active mining operations for a period of nearly six years.

CONSTRUCTION WORK.

Construction work, which was discontinued throughout the district, in August 1914, was resumed at many of the mines and mills in the spring of 1915.

Work at the Calumet & Hecla leaching plant was resumed in April. The building is enclosed and work on the tank and piping is well under way. Part of the plant probably will be ready for operation in the summer of 1916.

Ahmeek expended $175,943.29 for construction. The concrete foundation for a new steel shaft and rockhouse at No. 2 shaft was completed and the erection of the steel work will commence in March 1916. At the mill two additional stamps were installed and put in commission during the year.

Allouez spent $19,037.01 for construction. Two brick fireproof dries are being built, one at each shaft.

Isle Royale rebuilt the stamp-mill at a cost of $130,987.33 over the $100,358 insurance collected on the old mill.

Osceola spent $82,074.22 for new construction at all branches. Of this amount $15,212.87 was for new work at the stamp-mill.

At the Tamarack recrushing plant the building proper is finished and floors and launders are being put in. All the necessary machinery has been ordered, with the exception of the Hardinge mills. Tamarack expended $31,791.55 for construction.

At the White Pine considerable work was done on surface and at the stamp-mill and $351,438.07 was spent for construction.

New construction at the mines and mills of the Copper Range Consolidated cost $161,587.23 during 1915. The major part of this expense was made to secure greater quantities of power at a favorable cost. A low-pressure turbine was installed at the Champion mill, and a transmission line constructed from the mills to the mines.

Franklin expended $14,139.92 for construction at mine and mill. Houghton Copper spent $8,111.49 for construction of a rockhouse and a railroad connection. Quincy spent $25,382.04 for construction at the mine, and Victoria spent $9,252.81 for construction at mine and mill.

Total construction work at the Mohawk amounted to $43,373.44, which includes the cost of a new steel rock-house at No. 5 shaft.

The erection of a modern steel rockhouse was started at the South Lake. Total cost of construction for the year was $7,779.65.

DIVIDENDS.

Ten companies paid dividends in 1915. Calumet & Hecla paid out $5,000,000; Champion $3,100,000; Copper Range $1,182,003; Ahmeek $1,650,000; St. Mary's $1,280,000, and Osceola $1,057,650. The total amount paid out in dividends during 1915 was $15,189,653.

Assets were increased in many cases, and only six companies out of a total of 47 ended the year with a balance of liabilities.

MINE CASUALTIES.

The report of the Houghton county mine inspector showed a total of 34 casualties for the year ending Sept. 30, 1915. The total number of men employed was 16,005 and the proportion of casualties was 0.0021. The largest number of casualties was seven, at the Quincy and the Hecla Branch. Accidents from fall of rock appear to be the most numerous, 24 of the 34 being of this nature.

Considerable interest has been shown among mining men during the past year in the question of accidents in mines and their causes. The writer has read carefully the testimony of witnesses and the verdict of the jury in each of the 34 cases, as stated in the county mine inspector's report. In only eight cases out of the total of 34 can the accident be clearly attributed to carelessness on the part of the men killed. In these eight cases of apparent carelessness only two miners were killed, the others being timber-men, trammers and men doing minor jobs underground.

For details of production, costs, dividends, assessments, assets and liabilities see statistical tables.

DETAILS OF OPERATIONS OF THE MINING COMPANIES IN 1915

Ahmeek Mining Company.

Mine location: Ahmeek, Keweenaw county.
General Manager: James MacNaughton.
Superintendent: S. Russell Smith.
Controlled by the Calumet & Hecla Mining Co.

During the year 1915 Ahmeek produced 21,800,492 pounds of refined copper, at a total cost per pound of 7.96 cents. This cost includes 0.10 cents per pound for refining anodes to save silver values. Of the 948,914 tons hoisted only 40 tons was discarded in the rock-house, showing a percentage of discard of 0.004. The pounds of refined copper per ton of ore treated was 23.0. The success of the operations for the year is indicated by a total payment to shareholders in dividends of $1,650,000.00. Assets were increased during the year by $614,882.15.

Shaft sinking was continued in three of the four operating shafts. The bottom of No. 1 shaft is below the 20th level. The 18th and lower levels will be driven north to No. 2 shaft, with a grade towards No. 1, in order to permit all ground opened by these levels to be trammed to No. 1 shaft, thereby increasing the tonnage tributary to it.

In the No. 2 shaft the mass copper fissure vein north of the shaft is now open for a total distance of 2,105 feet from the 9th to the 18th levels inclusive, with the exception of the 12th level, on which no drifting has been done, as a large mass of copper is being removed from the intersection of the fissure and lode. The recovery during the year from these openings has been 1,488,000 pounds of copper, at an average cost, exclusive of smelting, of 1½ cents per pound. Mules are used for tramming with satisfactory results on several levels in both No. 1 and No. 2 shafts.

The erection of the steel work for a new rock-house at No. 2 shaft will commence in March 1916. This rock-house will be equipped with two 24-inch by 48-inch crushers, a poor rock crusher and a drop-hammer for treating mass copper. With the completion of this new rock-house the present central crushing plant will be used for treating ore from No. 1 shaft only.

Mining operations at shafts Nos. 3 and 4 were resumed in May. On the south side of No. 3 shaft, from the 11th to the 15th levels inclusive, a promising looking fissure vein has been found, but no drifting as yet has been done on it. All openings in No. 4 shaft have shown ore of average quality. Drop switches and transfer cars have been installed at shafts 3 and 4 and are working satisfactorily.

At the stamp-mill two additional stamps, Nos. 5 and 6, went into commission May 31 and August 31 respectively. The regrinding machinery for these units will be completed early in 1916. Stamp foundations and floors for stamps 7 and 8 are completed, the machinery has been ordered and both of these stamps should be in operation during the coming year The low-pressure turbine is giving good results and, in addition to supplying the necessary power for Nos. 5 and 6 stamps, is selling about 600 kilowatts to the Calumet & Hecla Mining Co.

A dam and reservoir of 3,000,000 gallons capacity has been built above the Hungarian Falls to provide additional fire protection for the Ahmeek, Tamarack, Osceola and Lake Milling companies.

Two diamond drill holes were put down from surface to locate and test the Calumet conglomerate; one in the S. E. ¼ of the S. E. ¼ of Section 29, T. 57 N., R. 32 W, and the other in the N. W. ¼ of the N. E. ¼ of Section 32, T. 57 N., R. 32 W. In the first hole the conglomerate was found to consist of two feet of very hard, compact felsite conglomerate

with a few flakes of copper near the top, underlain by one foot of soft, dark-red sediment.

In the second hole drilled the Calumet conglomerate consisted of three feet of shaly sediment above which were two inches of coarse sandstone bearing no copper. This second hole was continued through the Osceola amygdaloid, which was found to be 15 feet thick and carried very little copper at one point.

On May 1 the rate of wages was restored to that existing prior to the cut of September 1, 1914, and in June all employees received as a premium the wages forfeited under the reduced rate of pay from September 1, 1914, to May 1, 1915. On December 31, 1915, it was announced that a premium of 10% would be added to the wages of all employees of the company for the first six months in 1916. The directors felt that the employees, because of their loyalty and efficiency, should share in the existing prosperity due to the higher prices of copper.

Algomah Mining Company.

Mine location: Lake Mine, Ontonagon county.
Superintendent: Thomas Bennett.

After a period of idleness of over a year work was resumed in April, following a sale of delinquent stock which had been bid in by the company for non-payment of assessment.

Two hundred feet of drifting was done on the 40 foot level and a small stope put through to surface, in order to take out some of the ore lying between the first level and surface. This work was discontinued, however, after two months, as it proved unprofitable owing to the difficulty, without a suitable concentrating plant, of selecting by hand ore of sufficiently high grade (18%) to go direct to the smelter. The mine was then unwatered and shaft sinking resumed, which at the end of the year had reached a depth of 478 feet.

Shaft sinking will be continued during 1916. The shaft is sinking towards the point where the Lake, South Lake and Algomah properties join. It is believed by General Manager Edwards that at depth some of the lodes worked in the Lake and South Lake will be encountered on the Algomah property.

During the year 5,005 pounds of copper was sold at 18 cents per pound. The excess of liabilities on December 31, 1915, was $18,133.65.

Allouez Mining Company.

Mine location: Allouez, Keweenaw county.
General Manager: James MacNaughton.
Controlled by the Calumet & Hecla Mining Co.

Allouez treated 534,705 tons of ore during 1915, and the total production of refined copper was 10,043,459 pounds. The yield of refined copper per ton of ore treated was 18.78, and the total cost per pound was 9.31 cents.

The results of Allouez's operations for 1915 are very interesting when compared with the results of the three years previous to 1915. The total tons of ore treated, the total production of refined copper and the yield per ton of ore treated are all considerably higher than during the other three years. The mining expense per pound was reduced about two cents and the total cost per pound of 9.31 cents is a notable decrease.

The stopes tributary to No. 1 shaft were fully up to the average quality, and No. 2 shaft stopes were a little better than average in quality.

For increase in wages and premiums see Calumet & Hecla Mining Co.

Two dividends of $1.00 a share, amounting to $200,000.00, were declared during 1915. Assets were increased by $599,987.98.

Baltic Mining Company.

Mine location: Baltic, Houghton county.
General Manager: F. W. Denton.
Superintendent: Albert Mendelsohn.
Controlled by the Copper Range Consolidated Co.

The Baltic's operations for 1915 show a net profit of $949,965.40. The total production of refined copper was 12,028,947 pounds and this was sold at 17.40 cents per pound. The Baltic has $336,376.79 worth of copper on hand which is already sold and $232,939.06 worth of copper has been delivered and not paid for. The surplus of the company Dec. 31, 1915, was $1,440,576.25.

The improvements in the underground sorting of ore broken resulted in the remarkable yield per ton of ore stamped of 31.79 pounds. The cost per pound was 9.50 cents.

No. 2 shaft was the chief producer during the year 1915 and furnished about half of the total output for the year. The new ground opened in this shaft is good. A total of 54,240 cubic yards of stamp sand was run into the mine for fill.

Improved methods permit breaking and handling much leaner ground, and the sand fill makes possible more complete extraction and thorough exploration of the lode.

Calumet & Hecla Mining Company.

Mine location: Calumet, Houghton county.
General Manager: James MacNaughton.
Superintendent: John Knox.

During the year 1915 the C. & H. produced 72,613,320 pounds of refined copper, of which amount 71,030,518 pounds was produced by the mine and 1,582,802 pounds was recovered from the sand bank at Torch Lake. The recovery from 3,188,583 tons of ore treated from the mine was 22.28 pounds per ton. The total cost per pound of mine copper produced was 9.33 cents, and the price received for copper sold averaged 18.11 cents. Four dividends, amounting to $5,000,000, were paid during the year.

The Calumet conglomerate lode produced 51,738,588 pounds of copper, an average of 29.74 pounds per ton, at a total cost per pound of 8.69 cents. About 51 drills were at work during the year removing shaft pillars and cleaning up arches and the backs of old stopes. A total of 379,201 tons was obtained from this work. Not much change was found in the character of the openings in the Hecla and South Hecla branches.

The Osceola lode produced 19,291,930 pounds of copper, an average of 13.32 pounds per ton, at a total cost per pound of 9.71 cents. The openings on this lode continue to show about the same grade of ore. The product obtained from foot-wall stopes was about 31½ per cent of the total product of this branch.

No work was done on the Kearsarge lode during 1915. No work was done on the lands of the Manitou-Frontenac branch and no work of any kind was done at the St. Louis branch during the year.

At the mills all the 28 stamps are running, 17 on conglomerate and 11 on amygdaloid ore. Both the old and the new recrushing plants were in continuous operation during the year, except for an interruption of about seven weeks in July and August, due to the burning out of the turbine generator.

The results with pebble mills used in the new plant are so far superior to the Chilian mills in the old plant that it is intended to remodel the old plant. When this is completed there will probably be sufficient increased capacity to handle all the mill tailings and thus make all of the new plant available for sand bank tailings.

The comparative results for 1915 from the two plants on mill tailings are as follows:

	No. 1 Plant.	No. 2 Plant.	Both Plants.
Tons coarse tailings crushed	337,243	168,461	505,704
Pounds per ton in material treated	13.14	13.14	13.14
Pounds copper saved per ton	4.01	4.73	4.25
Pounds copper produced	1,352,869	796,858	2,149,727
Cost per pound, excluding smelting and selling	6.52c	4.36c	5.72c

The reclamation plant went into commission on a limited scale in June, but was interrupted by power trouble in July and August. Since September it has been running continuously, the number of mills in commission gradually increasing until full capacity was reached in December. At present there are 48 Hardinge mills in this plant regrinding sand bank tailings. This number will be increased by 16 Hardinge mills, now handling stamp-mill tailings, as soon as the old (No. 1) recrushing plant is remodeled to handle all tailings from the stamp-mills.

The reclamation plant consists of three units, namely, dredge, classifying house and conveyor, and No. 2 (new) recrushing plant. With three-quarters of the plant in commission, production at present is at the rate of 5,000,000 pounds of copper annually. The results from the operations of the reclamation plant are as follows:

Tons tailings treated	181,732
Pounds per ton in material treated	21.80
Pounds copper saved per ton	8.71
Pounds copper produced	1,582,802
Cost per pound, excluding smelting and selling	4.02c

Work on the erection of the leaching plant was resumed in April. The building is enclosed and work on the tanks and piping is well under way. The building contains eight sand tanks each 54 feet in diameter by 12 feet high with a capacity of 1,000 tons of sand. The cycle of operations proposed will require approximately 96 hours, so that the capacity of the plant will be 2,000 tons daily. The principal leaching agent will be ammonia and a contract for future requirements has been made with the Semet-Solvay Co. of Syracuse. It is hoped to have part of the plant in operation early in the summer of 1916.

At the smelter a new furnace, equipped with a mechanical pouring device and with a capacity of about 1,750,000 pounds per month, will probably be ready for operation by June 1, 1916.

Owing to improved conditions in the copper market, on May 1 the rate of wages was restored to that existing prior to the cut of Sept. 1, 1914, and in June all employees received as a premium the wages for-

feited under the reduced rate of pay from Sept. 1, 1914 to May 1, 1915. On Dec. 31, 1915, announcement was made that a premium of ten per cent would be added to the wages of all employees of the company for the first six months in 1916, it being considered proper, because of their loyalty and efficiency, that they should share in the existing prosperity due to the higher prices of copper.

The above statement of increased wages also applies to the following C. & H. subsidiaries:—Ahmeek, Allouez, Centennial, Isle Royale, Osceola and Superior.

Centennial Copper Mining Company.

Mine location: Calumet, Houghton county.
General Manager: James MacNaughton.
Controlled by the Calumet & Hecla Mining Co.

The gain from mining operations for the year 1915 was $142,439.81. Assets were increased by $248,483.81.

Centennial produced 2,347,500 pounds of refined copper, at a yield of 15.63 pounds per ton of ore treated. The total cost per pound, however, was 12.45 cents, the mining expense per pound being 11.21 cents.

No. 1 shaft is used entirely for transportation of men and material and no stoping or development work was done in that vicinity. To the north of No. 2 shaft openings showed average results. Some exceptionally good ground was encountered on the 31st and 32d levels. The drift on the 37th level which is being driven south to No. 1 shaft has shown copper at various points which warrant further inspection in the future.

No construction work was done during the year.

For increase in wages and premiums see Calumet & Hecla Mining Co.

Champion Copper Company.

Mine location: Painesdale, Houghton county.
General Manager: F. W. Denton.
Controlled by Copper Range Consolidated Company and St. Mary's Mineral Land Company.

Champion made a remarkable record in 1915. The total production was 33,407,599 pounds of copper at a yield of 36.17 pounds per ton of ore stamped. The cost per pound was 6.30 cents and the price received 17.40 cents, giving a profit per pound of 11.10 cents.

The tons of ore stamped, the pounds of copper produced and the yield of copper per ton were all much higher in 1915 than in any other year in the history of the company. After paying $3,100,000.00 in dividends,

the suplus at the end of the year was $1,815,868.46, as compared with $1,206,819.44 at the end of 1914.

All openings made during the year showed average values. The advisability of drilling into the foot and hanging for parallel lodes is clearly proved by the opening of a large area of rich ground between Nos. 2 and 3 shafts, back in what was previously supposed to be the foot-wall.

As at the other Copper Range mines, stamp sand is used for fill, and during the year 220,920 cubic yards was run into the mine for this purpose.

The notable increase in yield per ton of ore stamped is due chiefly to better sorting. The product of the regrinding mills (estimated at about two pounds per ton) is another factor.

General Manager Denton states that the mine is in excellent condition and the outlook favorable.

Cherokee Copper Company.

Location of property: Between the Bohemia and King Philip properties.

Superintendent: H. W. Fesing.

The Cherokee owns about 800 acres of well timbered land. Outcrops are numerous, and a great deal of the overburden is light. The Copper Range Railroad and the Stratton Timber Railroad both traverse the property, making it very accessible.

Exploration work was resumed in the summer of 1915. Work was started in the S. W. ¼ of Section 2, T. 51 R. 37. Two amygdaloids were uncovered by cross-trenches but showed nothing of interest.

Work was then started in the N. W. ¼ of Section 2. The cross-sections and cores from several holes drilled in the summer of 1911 showed an amygdaloid carrying some heavy copper with a general strike of N. 45° E. A number of pits were sunk on this line of strike and four of these uncovered the amygdaloid.

Two of these pits (Nos. 10 and 18) gave very interesting results. In the S. E. ¼ of the N. W. ¼ of Section 2 the bed was exposed for a width of 46 feet. The foot was composed largely of a sludge of chrysocolla in which were found many nuggets of metallic copper. For the first 10 feet from the foot the bed carried considerable heavy copper; the rest had copper here and there, with a little stronger showing towards the hanging.

A second pit (No. 18) was started 50 feet southwest of the one described above This was a well timbered pit, eight by nine, and was sunk seven feet in the bed. All the rock from this opening showed

strong mineralization, and this will probably be the site for a deep exploratory shaft.

Boiler, compressor, hoist and pumps will be installed in the spring of 1916. A shaft will be sunk to explore at depth the mineralized lode exposed in the pits and trenches.

Balance of assets Dec. 31, 1915, was $39,791.62.

Cliff Mining Company.

Location of property: Keweenaw county.
General Manager: James MacNaughton.
Controlled by the Calumet & Hecla Mining Co.

The balance of assets was reduced to $24,113.49, the sum of $12,025.64 being expended for exploration and development work during 1915.

No work was done at the temporary shaft. Seven diamond drill holes, totalling 3,686 feet, were put down to complete the cross-section from the Greenstone bluff to the most easterly part of the company's property.

Five holes, totalling 2,141 feet of drilling, were put down in Section 25 T. 58 N. R. 32 W. to explore the Ashbed lode. The lode in these drill holes was found to vary from 25 to 32 feet in thickness, being practically barren in two of the holes and carrying fine copper, not in commercial quantity, in the other three. Just above the Ashbed there is a bed of silicious sandstone varying from one inch to 18 inches in thickness, which also carries a little very fine copper.

The West lode is from six to nine feet thick and is separated from the main Ashbed lode by a bed of trap about 36 feet thick. In character it is very similar to the Ashbed, and carries a little copper. At the top of the West lode there is a well-defined slide.

Two holes, totalling 1,545 feet, were drilled in Section 1, T. 57 N. R. 32 W. to explore the Calumet conglomerate and Osceola amygdaloid lodes. One of these holes cut both lodes. The Calumet conglomerate was found to be a dark red, clayey to shaly sediment, 3½ feet thick and practically barren of copper.

The Osceola amygdaloid in this same hole looked encouraging, being 13½ feet thick, four feet of which carried a little copper. The overburden was too deep for trenching at the outcrop of the lode, so another hole was drilled. This revealed a very poor looking bed, scarcely recognizable as the Osceola, 20 feet thick, with very little copper. The showing was not considered sufficiently good to warrant further work at this point.

Contact Copper Company.

Location of property: Elm River, Houghton county.
Superintendent: George S. Goodale.

The operations of the Contact during 1915 consisted of further exploration of the property by diamond drilling. Four holes were drilled, showing a total of 5,271 feet for the year.

In two of these holes the Wyandot No. 8 lode was definitely located at depths of 450 and 950 feet from the outcrop. The last hole drilled in this preliminary section should cut the lode at about 1,550 feet in depth.

The drilling during 1915 furnished sections of the lode at depth from the outcrop of 450 feet, 950 feet and 1900 feet, corresponding roughly to what would ordinarily be the 3d level, 8th level and 17th level respectively in a shaft.

The lode where cut appears to be a big, strong amygdaloid, at least 50 feet in thickness. Supt. G. S. Goodale states as follows: "The reasonable certainty that we have established the true identification of this bed, and its favorable and promising character for a mineralized formation, taken together with its promising disclosure of mineralization in other underground developments, leads me to feel that the results of our work for the year are very satisfactory."

The company had on hand Jan. 1, 1916, a balance of $18,948.96 in cash.

Copper Range Consolidated Company.

Mine office: Painesdale, Houghton county.
General Manager: F. W. Denton.

Controls Copper Range Co., Baltic Mining Co., Trimountain Mining Co., and Atlantic Mining Co., and owns half of Champion Copper Co.

Various improvements in mining practice and the introduction of new mining and milling machinery resulted in a yield of copper per ton much higher, and a reduction in cost per pound much lower than ever previously obtained by the company. The total production of 37,035,642 pounds is 3,895,345 pounds larger than the best previous production in the history of the company.

The average yield of copper per ton for 1915 was 32.50 pounds, and the cost per pound 8.06 cents. Both of these are new records for the company. These improvements at the same time prolong the life of the mines; the lode is made more productive per unit of area, and results similar to or better than those of 1915 may be expected under average conditions.

While the great increase in the company's production in 1915 was due chiefly to the increase from the Champion mine, all the properties of the

Copper Range are now in excellent physical condition, and at the close of 1915 the reserves of developed stoping ground in the mines were greater than at the beginning of the year.

A total of $161,587.23 was spent for new construction at the mines and mills.

The net earnings of the company for 1915 were $9.00 per share. A dividend of $3.00 per share was paid on December 15, and the balance added to working capital.

The new sales office in New York, opened Jan. 1, 1915, has been a great success. Savings in commissions have been considerable over the previous arrangement. A surplus of several million pounds of unsold copper and the entire product of 1915 was all disposed of during the first ten months of the year. The average selling price of 17.404 cents per pound does not include the sales made during the last two months of the year.

The New Jersey company, which formerly held the shares of the Copper Range Consolidated operating companies, was dissolved Oct. 8, 1915. It is probable that the Baltic Mining Co. and the Trimountain Mining Co. will also be dispensed with during 1916.

Franklin Mining Company.

Mine location: Demmon, Houghton county.
Superintendent: Enoch Henderson.

During 1915 Franklin produced 1,314,969 pounds of refined copper, which was sold at an average price of 19.83 cents per pound. Production began in April and increased gradually to 250,000 pounds of refined copper in December

Franklin's operations during 1915 were confined to the development of the Allouez conglomerate and the driving of the exploratory crosscut on the 32d level.

Because of the limited openings in the conglomerate it was possible to work only a small number of men during the first half of the year. A crosscut was driven from the No. 1 amygdaloid shaft 540 feet to cut the Allouez conglomerate on the 27th level. This level was connected with the 37th level by a rock chute with a loading bin at its bottom to permit dumping ore on all the conglomerate levels. In August the installation of the electric haulage transfer system to transfer ore from the bottom of the chute in the conglomerate on the 37th level to No. 1 amygdaloid shaft was completed. This electric haulage has a carrying capacity greater than the hoisting capacity of No. 1 amygdaloid shaft which it serves. Drift-stoping on all conglomerate levels was then started and

was continued with a steadily increasing production to the end of the year.

There was no underground selection or sorting of ore as there were no worked out stopes to permit of discard. Out of a total of 151,269 tons hoisted, 29,251 tons was discarded in the rock-house. This discard was principally trap and footwall sandstone.

One of the most interesting points of Franklin's operations during 1915 was the easterly exploratory crosscut on the 32d level. This was driven 2,638 feet to a total distance of 4,000 feet from the hanging of the Pewabic amygdaloid. Two conglomerates, the Calumet and the Kearsarge, and 23 amygdaloids, including the Osceola amygdaloid, were exposed. Both conglomerates, the Osceola amygdaloid and 13 of the others were found to be barren. Seven of the remaining beds carried copper in small quantities and two carried sufficient copper to warrant drifting.

The opening work of the year put in sight new reserves of average value conglomerate ore amounting on Dec. 31, 1915 to 600,000 tons.

Production for 1916 up to 250,000 pounds per month has been sold for better than 25 cents per pound. Every effort is being made towards increasing production, and No. 2 conglomerate shaft will probably be reopened in the summer of 1916.

After remaining idle since July 24, 1913, the Franklin stamp-mill was overhauled and stamping of custom ore was resumed on March 29th. Since the first of August four heads have been in almost constant operation, stamping Franklin ore and custom ore from several other mines.

The surplus at the end of the year was $30,022.43.

Hancock Consolidated Mining Company.

Mine location: Hancock, Houghton county.
General Manager: John L. Harris.

Mining operations were resumed in March. The Hancock was one of the first companies to suspend operations in August 1914 because of the European war.

The total production of refined copper for the year was 871,124 pounds, of which 443,417 pounds was sold at an average price of 18.578 cents per pound.

The development work of the year was confined principally to drifting on lodes intersected at depth in No. 2 shaft at the 39th, 44th, 49th and 53d levels. Stoping was done in the upper levels on lodes Nos. 3 and 9 and in the lower levels on lodes 4 and 8.

The general average of the ground mined in the upper workings was

low grade. The development work at and below the 39th level exposed more promising copper bearing formations than in the upper workings.

General Manager Harris states that since operations were resumed last March a decided change for the better seems to have taken place in the lower workings, and from present indications further development work should show satisfactory results.

On the 30th level south there seems to be a very heavy slide fault, which north of the main crosscut is on the hanging wall contact which it follows for quite a distance. To the south there is a decided change; the physical appearance is entirely different from that on the north side, although showing copper for practically the entire distance.

Considerable stoping has been done some distance south of the main crosscut on a reddish trap zone from 6 to 8 feet thick, carrying considerable copper in the form of small grains up to walnut size, with occasional small slabs of copper in the seams. There appears to be no well defined foot or hanging wall; the copper occurs in the zone about parallel to the dip of the regular amygdaloid beds.

Considerable interest has been shown in the agreement between the Hancock and the Quincy Mining Co. for the joint operation of the Quincy No. 7 shaft. The details of this agreement as stated by Pres. John D. Cuddihy are as follows:

"An agreement, for five years, was entered into with the Quincy Mining Company in August for the joint operation of their No. 7 shaft, which was, heretofore, sunk to the 71st level to the boundary line of the Hancock property; drifts extended south and rock extracted within its ground up to the boundary line in the lower levels.

"The Pewabic lode in the territory of the Quincy Company south of No. 7 shaft and the territory of the Hancock Company being so accessible to this shaft, it was deemed advisable to join in the operation of the shaft in order to quickly gain access to the ground beyond the Hancock-Quincy boundary, and as it would require several years to sink and equip a subsidiary shaft to our No. 2 shaft into our territory near the Quincy boundary, the advantage to the Hancock Company in gaining access to this ground, at once, enables us to extend openings into our own territory, so that the subsidiary shaft from the bottom of No. 2 shaft to the 71st level can be sunk and raised at the same time from several levels, and, consequently, much time gained and money saved in equipping it to carry on operations in our own territory below the bottom level (71st) tributary to No. 7 shaft.

"About 75 acres of ground in the east half of the S. E. ¼ of section 22, and a very small area in the N. E. ¼ of the N. E. ¼ of section 27 was sold to the Quincy Mining Company for $191,250.00; also the sale of a

160 foot strip, about 1100 feet long, along the Hancock-Quincy boundary south of No. 7 shaft for $35,000.00.

"In this ground, a pillar is to be left during the life of the agreement to prevent caving or destruction of the workings of either company.

"We are to have the right to use No. 7 shaft of the Quincy Mining Co. for one-half of the time, or 12 hours each day, and pay one-half the cost of operation and one-half the cost of maintenance, with the provision that it may be increased another one-half upon payment of proportionate increase in rental if the Quincy Company should offer the additional time and Hancock Company is willing to accept it; a division of the cost of operation and maintenance of surface plant, including rock-house hoisting engine, etc.; a fixed charge per ton for transporting rock from rock-house to stamp-mill of the Quincy Company on Torch Lake; lease of one stamp head at the Quincy mill; a provision that the Quincy Company shall operate the head for the benefit of the Hancock Company and charge the Hancock Company for the operation the average cost of operation per stamp head for the entire mill.

"The mineral produced by the Hancock Company through the Quincy mill is to be smelted at the Quincy Smelting Works under a smelting contract agreed upon."

The Hancock has also purchased a sufficient amount of stock in the Lake Milling, Smelting and Refining Co. to entitle it to have ore which will be hoisted from shafts, other than Quincy No. 7, treated in the mills owned by that company.

Houghton Copper Company.

Mine location: North of the Superior mine, Houghton county.
Superintendent: R. R. Seeber.

In May a right of way for railroad connections was acquired and early in June a spur connecting the shaft with the tracks of the Superior Copper Co. was finished. Shipments then began from the stock-pile accumulated during development work and continued until September. The stock-pile contained about 8,140 tons, in addition to which 6,517 tons was shipped from underground work. The total product of refined copper was 156,766 pounds and the yield per ton of ore stamped was 10.69 pounds.

The yield of 10.69 pounds per ton was considerably poorer than was anticipated, so it was decided inadvisable at present to sink the shaft any deeper. The shaft-house was equipped with a rock crusher, motor and a small rock-bin, and underground work resumed in September.

Several good bunches of copper were encountered in the drift south of the shaft on the 620 foot level. The winze to the 1,020 foot level was

continued down 92 feet. The first 20 feet of this winze showed a lode well charged with heavy copper; for the next 75 feet a roll of the footwall cut out the lode; below this trap the lode showed considerable heavy copper again. At the 12th level a crosscut will be run to the West lode.

Balance of assets Dec. 31, 1915 was $24,763.49.

Indiana Mining Company.

Mine location: Indiana, Ontonagon county.
Superintendent: Thomas Bennett.

The work at the Indiana during 1915 was confined almost entirely to an endeavor to locate the "well-known" No. 2 drill hole at the 600 foot level, with the object of exploring it from that point to the bottom and thereby determining the exact position of the rich deposit of copper cut by the drill at 1,441 to 1,492 feet.

A chamber approximately 100 feet in diameter was opened around the theoretical position of No. 2 drill hole at the 600 foot level, but the hole was not found.

Late in the year it was decided to discontinue the search at the 600 foot level and to proceed directly to look for the deposit itself at the 1,150 and 1,400 foot levels. The shaft was unwatered to the bottom and drifting in search of the deposit is now under way at these two levels.

A geological examination of the drill cores and openings was made by Prof. A. C. Lane in August. Prof. Lane's general conclusion is that the much desired deposit lies a short distance east of the shaft at the 1,400 level and is a rather ragged aplite or felsite dike with a steep hade, about 12° to 18° more or less, at right angles to the dip of the beds, and that this dike is heavily charged with copper especially at the contact.

Prof. Lane also advises further exploration above No. 8 conglomerate in the horizon of the South Lake lodes.

The balance of assets at the close of the year was $14,574.35.

Isle Royale Copper Company.

Mine location: Houghton, Houghton county.
General Manager: James MacNaughton.
Superintendent: James E. Richards.
Controlled by the Calumet & Hecla Mining Co.

The operations of the Isle Royale during 1915 resulted in a profit of $498,277.41. A total of 9,342,106 pounds of refined copper was obtained from the treatment of 680,270 tons of ore, an average of 13.7 pounds per ton. The total cost per pound refined copper was 14.94 cents which

includes the expense of rebuilding the stamp-mill, reopening No. 1 shaft and sinking No. 7 shaft. These extraordinary expenditures totalled $183,293.35, or nearly two cents per pound. The mining expense was 10.56 cents per pound.

The reopening of No. 1 shaft was resumed in April. Hoisting ore from stopes on the 7th to the 12th levels inclusive started in August. From the 14th level to the bottom the shaft is filled with water which is now being removed. In December two drills were started drifting in the West lode and four stoping on the Isle Royale lode.

At the No. 2 shaft three drifts were extended north of the shaft in the West lode, a little over one-half of the ground opened containing copper. The drifts south of the shaft were in the Isle Royale lode, and about half of the ground contained copper.

At the No. 4 shaft about three-fourths of the ground opened contained copper. The 3d and 10th levels north have been connected to the old Huron mine workings.

At the No. 5 shaft 80 per cent of the ground opened contained copper, and at the No. 6 shaft about two-thirds of the ground developed showed copper.

At No. 7 shaft sinking from surface was resumed in May. The shaft was sunk about 40 feet in the lode by the end of the year. As soon as the concrete shaft-collar is completed, sinking will be resumed.

Isle Royale transported 211,964 tons of Superior ore at seven cents per ton and received $14,837.48. This reduced the cost of transporting Isle Royale ore over its own tracks to 3.17 cents per ton.

The first unit in the new stamp-mill went into commission June 7, just 5½ months after the old mill was completely destroyed by fire. The second unit was placed in commission July 9 and the third August 26. The mill has been in continuous operation since its completion and is now handling 2,000 tons daily. The cost of rebuilding the stamp-mill was $130,987.33 over the $100,358 insurance collected on the old mill.

Wilfley tables have been installed throughout the mill for the finished product and for the slimes. A Hardinge mill is being erected to regrind the richer of the coarse products. A low-pressure steam turbine of 600-kilowatts capacity has been installed and all mill machinery is now motor driven.

Mining operations were not interrupted during the rebuilding of the mill. Most of the ore was sent to the Lake Milling Company's plant at Point Mills, and when the capacity of this mill was exceeded, a part of the ore was handled at the Franklin mill and a part at the Tamarack mill.

Isle Royale invested $144,035.67 in Lake Milling, Smelting and Re-

fining Company stock and there are two units at the Point Mills plant stamping Isle Royale ore when furnished.

For increase in wages and premiums see Calumet & Hecla Mining Co.

Keweenaw Copper Company.

Location of property: Keweenaw county.
General Manager: W. J. Uren.

No work was done on the lands of this company during 1915.

During the year additional shares of stock of the Phoenix Consolidated Copper Co. were exchanged for shares of the Keweenaw Copper Co.

For statement of mining operations see Phoenix Consolidated Copper Co.

Lake Copper Company.

Mine location: Lake Mine, Ontonagon county.
General Manager: E. W. Walker.

Work at the Lake mine was resumed in April 1915, following a two-year shut-down on account of labor troubles and the war. The mine was filled with water up to about the 6th level, so bailing was started on May 12 and was continued until June 22, when the 11th level, the lowest in the mine, was reached. The mine was found to be in very good condition and little work was required to resume active mining operations.

Active production began late in July and the total output of refined copper for the year ending April 30, 1916 was 1,581,071 pounds. The yield of refined copper per ton of ore stamped was 26.42, and the price received was 20.149 cents per pound. The ore was treated at the Trimountain mill until that mill was destroyed by fire in March. The ore is now being stamped at the Baltic mill.

Careful sorting has about doubled the yield of copper per ton of ore stamped and the increase in the cost of mining has not been great. The production for the year came from all levels in the mine with the exception of the 11th, where the work was confined to crosscutting in both the hanging and foot walls to locate the copper-bearing portions of the lode and to determine the width of the lode. Most of the ore came from the main Lake lode, with a small amount from the East lode. Supt. E. W. Walker states that "on the whole, the results have been quite satisfactory, and it seems reasonable to expect that the mine can continue to operate at a profit, especially with an increase in output."

Lake Milling, Smelting & Refining Company.

This company now has six heads at mill No. 1, Point Mills, and two heads at mill No. 2, formerly the little Tamarack mill, Hubbell.

An adjustment was made between Allouez and Centennial to make their holdings of stock of this company more nearly conform to their stamping requirements, the Allouez Mining Co. paying the Centennial Copper Mining Co. $109,516.05 for 10,000 shares of stock of the Lake Milling Co.

The present holdings of Lake Milling stock are as follows:

Allouez Mining Co	36,164 shares
Centennial Copper Mining Co	16,164 shares
Hancock Consolidated Mining Co	10,000 shares
Isle Royale Copper Co	18,836 shares
Superior Copper Co	18,836 shares

At the No. 1 mill, Point Mills, No. 1 head went into commission July 13 and is handling Hancock ore. Very little other construction work was done during the year. Capacity will probably be increased by means of rolls in the near future and additional power will be required.

The No. 2 mill, Hubbell, handles all the Centennial ore in one unit, the other unit being used for Allouez. Construction work for two new heads has been started. One head is to be built south and one north of the present mill and these will be known as Nos. 1 and 4. The stamps will be Norberg Compound and the wash equipment similar to that of the present units.

Additional fire protection has been provided by building a dam and reservoir above Hungarian Falls.

La Salle Copper Company.

Mine location: South of Osceola, Houghton county.
General Manager: James MacNaughton.
Controlled by the Calumet & Hecla Mining Co.

The mine was closed down early in August, 1914, on account of the war. In the spring of 1915 preparations were begun for resuming mining. The water in No. 1 shaft was lowered to below the 15th level and in No. 2 shaft to the bottom. Ore shipments to the Franklin mill began July 13.

At the No. 1 shaft the mining during 1915 consisted of stoping on three levels and a little drifting on one. The copper content of the ground was variable, the average being rather low.

At No. 2 shaft mining operations consisted of driving openings on

both sides of the shaft on three levels and stoping on one to the north. In general the ore is better than at No. 1 shaft. Preparations have been made to resume sinking this shaft, as soon as possible.

On Dec. 31, 1915 it was announced that a premium of 10 per cent would be added to the wages of all employees for the first six months in 1916.

Operations during 1915 resulted in a decrease of assets of $15,522.25. The total production for the year was 782,493 pounds of refined copper, but the yield of copper per ton of ore treated was only 9.67 pounds.

Mass Consolidated Mining Company.

Mine location: Mass, Ontonagon county.
Superintendent: E. W. Walker.

Mass produced during 1915 a total of 4,638,452 pounds of refined copper, at a total cost per pound of 14.37 cents. The copper was sold at 18.363 cents per pound. The yield of copper per ton of ore stamped was 14.35. The gain in cash assets during the year was $167,473.95.

The main Butler lode produced 227,628 tons and the Evergreen lode 62,083 tons. The north Butler, south Butler, Ogima, Knowlton and No. 3 lodes were also producers.

Development work was carried on in both "B" and "C" shafts, and there are now sufficient reserves on the Butler lode alone to last for at least three years at the present rate of extraction. Production was increased to the capacity of the mine and milling facilities.

On the 8th level at "B" shaft a crosscut was run in the footwall of the Evergreen lode to intercept the lodes which have been opened up at the South Lake property. Some very good ground was found in places.

Considerable stoping has been done on the Butler footwall lode in some of the lower levels. In several places the mineralization is of commercial value, and it is hoped that at greater depth it may prove to be of still greater value.

The old Evergreen workings above the 6th level are being drained of water, which will make available a considerable amount of very good ground.

Developments throughout the mine during 1915 have shown up ground equal to that of former years and in some instances considerable improvement is shown. Production will be further increased during 1916.

Mayflower Mining Company.

Location of property: East of Kearsarge and Wolverine mines, Houghton county.
Superintendent: George S. Goodale.

The work on the Mayflower property during 1915 was a continuation of the investigation of the geological conditions affecting the Mayflower lode.

One diamond drill was operated in hole No. 41 and the total footage drilled for the year was only 822 feet.

Hole No. 41 is located farther west than the other holes and should intersect the Mayflower lode much deeper than encountered elsewhere. To a depth of 1,857 feet the drill passed through firm and undisturbed ground; from this point to a depth of 2,569 feet a succession of crushed and shattered strata was encountered, which made drilling very difficult and progress slow. Drilling was interrupted for nine months by the loss of the drilling bit.

The St. Louis conglomerate was developed from 1,834 to 1,857 feet and was found to be dipping at a flatter angle at this depth.

Balance of assets Dec. 31, 1915 was $52,990.74.

Michigan Copper Mining Company.

Mine location: Rockland, Ontonagon county.
Superintendent: Samual Brady.

After a suspension of all active mining operations for a period of nearly six years, work was resumed at the Michigan in July.

An old incline shaft, which had been sunk to a depth of about 225 feet upon the hanging side of the Butler lode, was slected for enlargement from 5 x 8 to 8 x 14, with a view of ultimate enlargement to one 8 x 20 should the results of the explorations justify it. The work of enlarging and sinking this shaft, known as "E" shaft, was started early in September, and it is intended to continue the shaft on a dip of 49° to a depth of 603 feet, from which level it is proposed to crosscut the formation both north and south for extended distances to prove the value of the known copper-bearing lodes of that locality.

Strong lines of shearing were found crossing the formation at acute angles with the general strike and carrying more or less copper in contact with the Butler lode. While the work was in contact with the hanging side of the Butler formation, upon the foot side of the shaft the Butler lode was found to be marked by a crossing some 10 feet wide, which was well charged with barrel copper and stamp rock. This crossing, the strike of which was approximately at a right angle to that of the Butler lode, indicated an entirely different and independent line of mineralization from that following the lines of shearing. At a point near the 5th level where the line of the shaft seemed to penetrate the hanging of the Butler lode for a short distance, the lode was found to be well charged with copper.

Crosscutting and testing the formation from the 603 foot level will probably be started about the middle of May 1916.

Mohawk Mining Company.

Mine location: Mohawk, Keweenaw county.
Superintendent: Theo. Dengler.

Mohawk had a very satisfactory year in 1915. Operations showed an increase of over two pounds of refined copper per ton of ore stamped and a notable decrease in the cost of production, compared with results of 1914. The total product of refined copper was 15,882,914 pounds, at a yield per ton treated of 19.15 pounds. The total cost per pound including construction was 7.48 cents. A total of $43,373.44 was expended for construction, and two dividends, amounting to $600,000.00, were made during the year. The net profit for the year was $1,511,575.73.

At No. 1 shaft efforts are now being directed toward extensive sinking and drifting for increased production to compensate in part for the ultimate elimination of No. 2 shaft. The openings in general in this shaft indicate the necessity of considerable underground selection of many stretches of ground.

No. 2 shaft is in process of elimination. No. 3 shaft was discontinued early in the year.

At No. 4 and No. 5 shafts all drifting during the year showed a very fair mineralization. The new steel rock-house at No. 5 shaft was completed and put into commission December 20.

At. No. 6 shaft the drifting as a whole has shown fair mineralization. Work in this shaft has been directed chiefly toward drifting and sinking in preparation for an ultimate increased capacity to offset the elimination of Nos. 2 and 3 shafts. As this shaft increases in production the operating shafts will be reduced to four in number, the combined output of which will be ample to supply the mill.

The scale of wages was advanced an average of 15 per cent over that in force in January 1915 and since June 1915 all employees have received a bonus of 5 per cent on their earnings. For the month of January 1916 all employees will receive a bonus of 10 per cent on their earnings.

Naumkeag Copper Company.

Mine location: Houghton, Houghton county.
Superintendent: Sidney S. Lang.

The exploratory work of the Naumkeag during 1915 was confined to the workings from the Dakotah Heights adit, which is at the north end of the property, just south of the county road.

President J. Park Channing states that "the exploration up to date shows that there is a shoot of copper bearing ground in the northern part of the property which undoubtedly is worthy of development in depth, but this should not be done until the whole possible copper formation has been explored on the adit level."

New Arcadian Copper Company.

Mine location: East of Quincy mine, Houghton county.
General Manager: Robert H. Shields.
Mining Engineer: H. W. Fesing.

Development operations were continued without interruption during 1915 and were conducted along the lines of the previous year. Mineralization of the New Arcadian lode has been proven for a depth of 1,250 feet and for a length of 1,100 feet.

During the year three mill tests were made at the Franklin mill. The number of tons of ore treated was 3,845 and the yield 79,209 pounds of refined copper, or 20.62 pounds per ton. The copper was sold at an average price of 17.856 cents per pound.

The development work of the year consisted of sinking No. 1 shaft from the 900 foot level to the 1,250 foot level; continuing the east crosscut on the 900 foot level to expose No. 8 conglomerate; crosscutting east from the shaft to the lode at the 1,050 and 1,250 foot levels; drifting north and south on the 250, 900, 1,050 and 1,250 foot levels, and a limited amount of stoping on the different levels. Work was also started at the proposed site of No. 2 shaft, about 1,850 feet south of No. 1 shaft, where a former exploratory shaft was continued in depth to 50 feet, at which depth crosscuts were driven east and west across the formation.

Mining Engineer H. W. Fesing states that the openings made during the year have shown persistence of mineralization in varying degree, both in lateral openings and in depth, while the points at which the little stoping has been done have shown ground of good grade.

No. 8 conglomerate was intercepted about 380 feet east of the New Arcadian amygdaloid in the east crosscut on the 900 foot level and where cut, the conglomerate was found to be mineralized to such an extent as to warrant further exploration.

In the lower crosscuts east from the shaft the lode was intercepted much sooner than in the levels above, indicating a flattening of the dip with depth. If this condition continues the shaft will cut the lode at a depth of about 2,000 feet.

The various crosscuts east from the shaft to the lode being worked have passed through a number of amygdaloids; one of these, encountered

generally from 12 to 20 feet east of the shaft, is particularly strong looking, of good width and mineralized. In cutting the station at the 1,250 foot level this amygdaloid was found to be heavily mineralized and is worthy of further attention.

Prof. A. C. Lane visited the mine in August and reported as follows: "I am led to the interesting conclusion that your lode is very likely the Isle Royale lode of the Isle Royale mine, though it appears somewhat richer where you have opened it. If it continues as good as is exhibited on the 250 foot and 900 foot levels, I should judge that by mining the better portion of the lode you should be able to maintain the percentage of mineral shown in your mill runs (31 pounds to 34 pounds per ton).

"On the other hand, and this implies a correction in our previous report, I am sure it has nothing to do with the horizon opened in the old Arcadian, but is probably the horizon of the top of No. 101 (p. 449 of the Arcadian section)* which shows a trace of copper there, in thickness 269 feet, below the horizon then worked, which may now be worth examination.

"Conglomerate 8 seems to be entirely cut out by a slide fault in the Torch Lake section and some of the Oneco holes. The occurrence of a small area of copper rock in conglomerate 8 itself in your 900 foot cross-section raises the question whether to the north or where this fault cuts it off it will prove richest."

A special meeting of the stockholders of the company was held in February and unanimously confirmed the sale of 160 acres of its lands comprising the S. W. ¼ of section 9, 55-33, to the New Baltic Copper Co. for the sum of $40,000 cash and 14,000 shares of the capital stock of that company.

The present hoisting and machinery equipment is entirely inadequate and it has been decided to install a larger equipment which will provide for the exploration of the lode to a depth of at least 2,500 feet.

New Baltic Copper Company.

Location of property: East of Franklin mine, Houghton county.
General Manager: Robert H. Shields.

Exploratory work was begun in November on the N. W. ¼ of the N. E. ¼ of section 16, T. 55 N. R. 33 W., and consisted of trenching and diamond drilling for the purpose of definitely locating the outcrop of the New Arcadian lode and No. 8 conglomerate.

Hole No. 5 was drilled south 45° E. on a dip of 50° and was sunk to a depth of 481 feet, cutting the No. 8 conglomerate at 409 feet. The

*Michigan Geological Survey, Publication 6, Volume I.

conglomerate was found to be fully 40 feet in width and the core showed mineralization. This is the same conglomerate which the New Arcadian found to be well mineralized some 4,000 feet south in their east crosscut on the 9th level. This hole No. 5 also cut an amygdaloid at a depth of 106 to 116 feet and the core showed considerable fine copper.

Hole No. 6 was started at the same point as No. 5, the dip, however, being vertical, and cut No. 8 conglomerate at a depth of 513 feet, where it was found to be 60 feet wide. The conglomerate was reached at a much shallower depth than was expected, indicating either a fault or a marked change in the dip. This hole passed through an amygdaloid at 203 to 212 feet, over two feet of which was well charged with shot copper.

Hole No. 7 was located 800 feet N. 45 W. of hole No. 5 and was drilled vertically. A well mineralized amygdaloid was cut at 271 feet, continuing for over 16 feet, and showing good mineralization for fully seven feet. Another amygdaloid was cut at a depth of 487 feet, continuing for ten feet, seven feet carrying copper and two feet very rich. This hole will be continued until it reaches No. 8 conglomerate.

The New Baltic purchased from the New Arcadian Copper Co. 160 acres of mineral land, adjoining the New Baltic property to the northwest, for $40,000.00 in cash and 14,000 shares of the capital stock of the company. This gives the New Baltic an area of about 400 acres on the dip of the New Arcadian lode.

The results of the diamond drilling and the favorable developments at the adjoining New Arcadian mine indicate a bright future for the New Baltic. It is the intention of the management to sink a shaft on the New Arcadian lode as soon as its outcrop is determined, and by lateral openings from this shaft to explore not only the New Arcadian lode but the whole western part of the property, which from the diamond drill explorations, is known to contain a number of mineralized beds, including No. 8 conglomerate.

North Lake Mining Company.

Mine location: Lake Mine, Ontonagon county.
General Manager: R. M. Edwards.
Superintendent: Thomas Bennett.

When work was resumed in May 1914 the crosscut at the 300 foot level was continued in order to cut the extension of the lodes being developed on the South Lake property. This crosscut, however, broke through into the overburden at 730 feet and it then became necessary to sink an inclined winze to a greater depth, before going ahead with

the crosscut. The winze was sunk 200 feet on an incline of 30° and crosscutting was resumed at the 400 foot level.

During 1915 this crosscut to the northwest at the 400 foot level was extended 252 feet from the bottom of the winze. Three very promising looking amygdaloid lodes were cut and all three carried copper. It is believed that they probably correspond to the South Lake lodes Nos. 1, 2, and 3.

Only a small amount of opening was done on these lodes because the work again broke through into the overburden.

Shaft sinking was resumed in August and will be continued to the 800 foot level, at which depth the three copper bearing lodes will again be opened up by a crosscut. A crosscut will also be driven southeast at the 800 foot level to explore lodes known to exist in that direction.

Balance of liabilities Dec. 31, 1915 was $15,556.20.

Old Colony Copper Company.

Location of property: Calumet, Houghton county.
Superintendent: George S. Goodale.

The exploratory work on the Old Colony property during 1915 was a continuation of the diamond drill investigations of the Mayflower lode. A total of 8,319 feet was drilled during the year ending November 19, 1915.

Considerable crushed and disturbed ground was encountered in the holes and this condition retarded progress. In two of the holes the Mayflower lode was found to be mineralized with fine copper.

President H. F. Fay states that the company will soon be in a position to start a shaft to develop the mineral deposit which has been so persistent in each hole drilled.

Onondaga Copper Company.

The Onondaga Copper Company was organized April 22, 1912, to acquire and develop the mineral rights underlying about 10,000 acres of land situated in Ontonagon county, west of the Ontonagon river.

Diamond drilling was started in August, 1912, and was carried on continuously until September 21, 1914, when the work was suspended temporarily.

Five holes were drilled in section 14, T. 49 W. R. 42 N. Four of these holes were drilled practically at right angles to the formation and gave a continuous cross-section of the series in section 14 from the southeast corner to a large felsite outcrop in the northwest quarter of the section. The fifth hole was drilled northwesterly under the felsite to determine the contact and the possibility of mineralization at that

point. The hole was drilled to a depth of nearly 2,000 feet, but failed to reach the contact.

The sixth hole was drilled in the S. E. ¼ of section 4, 49-42. Holes seven, eight and nine were then drilled, making a complete cross-section from the southeast corner of section 14 to the northwest corner of section 4. With the completion of the ninth hole September 21, 1914, drilling was suspended.

While some of the cores from this cross-section showed copper, none showed copper in commercial quantities.

In the spring of 1915 arrangements were made for the exploration of lands within the Nonesuch basin. Several miles of road were built through the woods to section 34, 50-43, and drilling was started there in July. This drilling was started near the northern boundary of the section and was continued by a succession of drill holes, each hole exploring the territory farther south, until finally a drill hole at the extreme southeast corner of the section passed through the Nonesuch lode at a depth of about 1,100 feet. This hole, however, did not show any copper values.

Pres. R. C. Pryor, who is directing the exploration work, is encouraged by the determination of the location of the lode and hopes by further drilling to find some mineralized portion of the lode on the company's property.

Balance on hand Feb. 1, 1916 was $46,585.10.

Osceola Consolidated Mining Company.

Mine location: Osceola, Kearsarge and Tamarack, Houghton county
General Manager: James MacNaughton.
Superintendent: Frank H. Haller.
Controlled by the Calumet & Hecla Mining Co.

Osceola had a very successful and profitable year in all three branches during 1915. Dividends were declared amounting to $1,057,650.00 and the assets were increased by $553,210.20. The total production was 19,731,472 pounds of refined copper, at a yield of 14.5 pounds per ton of ore treated. The total cost per pound refined copper was 10.03 cents. During the year $82,074.22 was expended for new construction at all branches.

Osceola Branch:

The Osceola branch made a better showing in 1915 than for a long time past, in fact, it made a fair profit for the first time in six years or more. An excellent grade of ore was found in the extreme south work-

ings and the operating cost was lowered considerably. The Osceola branch has a promising future.

The best showing in the mine in recent years was opened up over 2,500 feet south of No. 6 shaft on the 42d level and the three levels above. Development work was pushed on these leve's all through the year and at present half the regular product is obtained from that territory. The ground along the southern boundary will be opened up as rapidly as possible.

A diamond drill hole was started horizontally in the hanging wall of the Osceola lode at a point 2,750 feet south of No. 6 shaft on the 42d level to explore for and determine the character of the Calumet conglomerate lode. The drill passed through the Calumet amygdaloid at 200 feet without showing any copper and continued through various other amygdaloids and traps. The drill hole passed through the Calumet conglomerate at a horizontal distance of 712 feet from the Osceola lode, where it was found to be a dark, fine-grained sandstone only a few feet thick and barren of copper.

The construction work at No. 3 shaft, interrupted in August 1914, was resumed in the spring of 1915. The plant at this shaft was put into condition for service; several of the old levels are being opened up and equipped with tracks and tram cars; some ore is being hoisted for shipment to the mill. If milling facilities permit, No. 3 shaft should yield a substantial product during 1916.

Osceola branch produced 3,882,069 pounds of refined copper at a cost per pound, excluding mill construction, of 12.34 cents.

North Kearsarge Branch:

This branch had a very successful and profitable year and is in good shape to make even a better showing in 1916. When the production from South Kearsarge begins to lessen, North Kearsarge can make up the loss in tonnage. While the ore may not be as rich, tonnage costs will be nearly as low.

The production of refined copper was 7,886,579 pounds and the cost per pound, excluding mill construction, was 10.99 cents.

Improvements in drill steel, drilling machines and methods brought about an increased rate of stoping at No. 4 shaft, which helped to reduce costs quite materially during 1915. It is expected that these improvements will continue to show good results as fast as they can be put into effect elsewhere in the mine, and that the cost per ton in 1916 will be somewhat less than the best showing made thus far.

The new ground opened by drifting in No. 1 shaft is rather above the average for that shaft. The workings at No. 4 shaft are improving with depth. The whole plant and shaft at No. 3 was completely over-

hauled and put in good condition. This shaft could be put in commission on short notice and could be made to produce a substantial tonnage if stamping facilities were available.

South Kearsarge Branch:

This branch made the largest production in its history in 1915. Costs per ton were lower than in any previous year except 1911, when wages were much lower than during 1915. It has not yet become necessary to reduce production because of exhaustion of reserve mining areas, and the recovery of copper per ton of ore treated has not lessened to any great extent.

The production of refined copper was 7,962,824 pounds, at a yield per ton of 16.72 pounds. The cost per pound, excluding mill construction, was 7.77 cents.

Mining the pillars of No. 2 shaft at the bottom level (16th) was started in June. This ground will be mined out rapidly during the next few years and will yield about 250,000 tons. The estimated reserves at this time, exclusive of the shaft pillars, are about 450,000 tons.

In May the upper levels between the two shafts began to cave and continued moving for several months. The surface of the ground over an area of about two acres subsided from two to ten feet and communication between the shafts was blocked all the way down to the 15th level.

For increase in wages and premiums at Osceola Consolidated see Calumet & Hecla Mining Co.

Phoenix Consolidated Copper Company.

Mine location: Between Phoenix and Eagle River, Keweenaw county.
General Manager: W. J. Uren.

Development work on the Ashbed lode was continued during 1915. No. 1 shaft was sunk 537 feet and the total depth is now 1,415 feet. Total openings for the year amounted to 8,598 feet.

Drifting along the hanging wall opened up fair copper ground. In April an exploratory crosscut was started southerly across the lode on the 6th level west. The lode is wide and before reaching the footwall good copper ore was found. Drifting along the footwall was started in June and has shown fair to good copper values. Towards the latter part of the year the 7th and 8th levels east reached this footwall portion of the lode and have been in fair to good copper ore.

For drainage and ventilation an old adit about 1,100 feet east of No. 1 shaft was reopened. The mouth of this adit is near the village of Eagle

River, and years ago it was driven south about 3,100 feet to connect with workings on the Ashbed lode.

There are two vertical shafts "A" and "B" on this adit, and in order to connect between the shafts the adit south of "A" shaft was driven to a point 56 feet from the adit north of "B" shaft by the end of the year.

The stamp-mill will be overhauled and a mill test made during the summer of 1916.

Quincy Mining Company.

Mine location: Hancock, Houghton county.
General Manager: Charles L. Lawton.

Quincy produced 22,054,813 pounds of refined copper during 1915, and realized a profit on silver of $11,829.08. The business income for the year was $1,873,674.69, and a total of $880,000.00 was paid in dividends.

The ground developed by the opening work was of about the usual quality and the mine as a whole did very well throughout the year. The extreme north end produced a low grade ore at times but the central portion of the mine, throughout No. 6 shaft workings, was particularly good. The showing of ore at the bottom of the mine in the new openings, with the exception of two low-grade drifts south of No. 2 shaft, is better than for several years.

No. 7 shaft was repaired for the purpose of handling both Quincy and Hancock ore.

No. 2 shaft produced the lowest tonnage and the lowest grade of stamp-rock but the largest amount of mass copper, so that the combined recovery of refined copper per ton of ore stamped was the highest of all the shafts. There are three branches of the Pewabic lode being mined in this shaft, all producing the different grades of ore that make up the general average. When the lode is rich in mass copper and barrel work, the stamp-rock is generally of lower tenor and vice versa.

In the No. 6 or Pewabic shaft, three branches of the Pewabic lode are being mined, and a small amount of work is being done on the Mesnard epidote lode. The openings from this shaft developed copper ground better than the average of the mine as a whole. The extension of some of the old upper levels developed ground that averages with the best stamp rock of the mine.

In the No. 8 or Mesnard shaft, four branches of the Pewabic lode were mined during the year, though only three are active at present. The shaft produced a fair grade of ore throughout the year.

No. 9 shaft, which is bottomed at a depth of about 2,900 feet, has remained idle, except for the pumping of water on the third and fourth levels.

Air blasts were more or less numerous throughout the year, but were not very serious or of great magnitude. Greater attention was paid to building the rock-rib-packs at the top and bottom of the stopes, above and below each level, and these packs have restricted and curtailed the extension and effect of the air blasts, and have permitted a higher extraction from the lode.

At the stamp-mills a great deal of repair and betterment work was done. Twenty-four small type bull jigs were installed in No. 1 mill and 12 have been ordered for No. 2 mill. Three more Sturtevant rolls were installed at No. 1 mill, making four rolls now in operation in each of the mills. Two 36 inch by 8 foot Hardinge ball mills have been ordered, one to be installed in each mill.

The smelter was very busy throughout the year, especially during the latter half, owing to the increase in custom work, and is now running pretty well up to its capacity.

About 80 acres of mineral land was purchased from the Hancock Consolidated Mining Company for $226,250.00. This ground will be mined at depth from shafts 2 and 7. See Hancock Cons. Mining Co.

On May 1 wages at the mine were restored to the basis existing prior to September 1914, which was the highest rate ever paid employees, but with the advance in the price of copper wages were increased about 7½ per cent December 1, and another advance of about 7½ per cent will take effect March 1, 1916.

South Lake Mining Company.

Mine location: Greenland Junction, Ontonagon county.
General Manager: R. M. Edwards.
Superintendent: Thomas Bennett.

During the year 1915 a mill test of 3,993½ tons of ore was made at the Franklin mill. This ore came from the drifts on all the lodes opened and several trial stopes on lodes Nos. 1, 2 and 3. The mineral was smelted at the Michigan Smelter and the net return of refined copper was 61,637 pounds, or 15.4 pounds per ton.

No. 1 lode on the 300 foot level has probably shown the most even mineralization, while lodes Nos. 2 and 4 on the 600 foot level have shown the richest ore.

The long crosscut south on the 600 foot level was continued 428 feet. The crosscut on the 300 foot level was extended north to cut the Butler lode, which overlies No. 1 lode about 300 feet at right angles to the formation.

The Butler lode was encountered at 415 feet from the hanging of No. 1 and the Butler hanging was reached at 506 feet. The Butler

lode was found to be 91 feet thick horizontally and carried good copper values on both foot and hanging sides. Drifting along the hanging also showed good copper. The Butler lode will also probably be reached in the 600 foot crosscut south.

During the summer Prof. A. C. Lane made an examination of the various lodes opened. His conclusions were as follows:

"1st—That the lodes found dipping north in the 300 crosscut north of the shaft are the same as those found dipping south in the 600 crosscut south of the shaft.

"2nd—That one of these lodes, probably No. 2 in the 600 crosscut, or possibly a combination of No. 1 to No. 3, is the same as the lode mined by the Lake Copper Co., commonly known as the Lake lode.

"3rd—That the continuation of the 600 crosscut south should cut the Butler lode dipping south.

"4th—That the lodes south of the shaft are somewhat faulted by two sets of faults, while those north of the shaft are apparently undisturbed."

The erection of a modern steel rock-house will probably be completed by March 1, 1916, when production will begin and will be increased as rapidly as possible.

Excess of quick assets Dec. 31, 1915 was $16,958.11.

St. Mary's Mineral Land Company.

Agent: F. W. Nichols, Houghton.

St. Mary's enjoyed a very prosperous year in 1915, due to the record production of the Champion mine, half of which is owned by St. Mary's.

A total of $1,550,000 was received in dividends from the Champion, and St. Mary's distributed $8.00 per share to its stockholders.

No sales of mineral ground were made during the year. Oak and pine only on 760 acres were sold for $3,300.00 and surface rights on 20 acres for $300.00.

The real property of the company Dec. 31, 1915 consisted of 93,012.69 acres, besides the mineral rights to 14,132.96 additional acres.

Superior Copper Company.

Mine location: South of Isle Royale mine, Houghton county.
General Manager: James MacNaughton.
Superintendent: Ocha Potter.
Controlled by the Calumet & Hecla Mining Co.

Superior made a gain of $245,017.27 from mining operations during 1915. The purchase of 18,836 shares of the Lake Milling, Smelting & Refining Company's stock for $240,000.00 and the assessment of

$5,615.17 account the same company, however, resulted in a decrease in assets of $597.90.

From 212,051 tons of ore treated, 3,866,484 pounds of copper was obtained, an average of 18.23 pounds per ton. The total cost per pound was 12.29 cents.

At No. 1 shaft the ground broken has shown enough copper to warrant shipment to the mill, although the copper is very fine, almost no mass being found.

The only development work on the Superior lode was on the 16th level south, where 216 feet was driven, about half of this distance being in stoping ground of below average quality.

Stoping reserves on the Superior lode were lessened rather than increased during the year. Development work is now being pushed to the limit.

At the No. 2 shaft the 18th level was extended north 580 feet, but no ground worth stoping was found.

For increase in wages and premiums see Calumet & Hecla Mining Co.

Tamarack Mining Company.

Mine location: Calumet, Houghton county.
General Manager: James MacNaughton.
Superintendent: John T. Been.
Controlled by the Calumet & Hecla Mining Co.

The operations of the Tamarack for 1915 show a great improvement over those of 1914. As much ore as possible was extracted, to take advantage of the high price of copper, without carrying on development work.

The total production of refined copper was 3,888,150 pounds and the yield per ton 17.9 pounds. The total cost per pound refined copper was 17.07 cents and the price received was 19.10 cents per pound. Assets were increased during the year by $308,987.72.

The mining operations during the year consisted of 285 feet of drifting on the Osceola amygdaloid in No. 2 shaft and 590 feet of drifting on the 20th level south in No. 3 shaft.

No. 1 shaft was used exclusively for pumping. In No. 5 shaft the 29th level crosscut between this shaft and No. 2 was cleaned out and timbered, it being necessary to keep this line of communication between the two shafts so that it could be used in case of accident. The total depth of No. 5 shaft is 5,308.5 feet from surface.

At the recrushing plant the building proper is finished and floor and launders are being put in. All necessary machinery has been ordered,

with the exception of the Hardinge mills, which have been delayed pending experiments now being made.

Trimountain Mining Company.

Mine location: Trimountain, Houghton county.
General Manager: F. W. Denton.
Superintendent: Richard Bowden.
Controlled by the Copper Range Consolidated Co.

Trimountain produced during 1915 a total of 8,302,896 pounds of refined copper at a yield per ton of 23.75 pounds. The total cost per pound was 9.53 cents and the price received was 17.404 cents per pound, giving a profit per pound of 7.88 cents.

Openings made during 1915 showed no marked change from the past two or three years. The higher yield of copper per ton stamped was due to improvement in underground handling of ore broken.

No. 1 shaft, which was abandoned as a working shaft several years ago, will be used as a chute to take waste stamp sand underground for fill.

The management expects further improvement in results.

Victoria Copper Mining Company.

Mine location: Victoria, Ontonagon county.
Superintendent: George Hooper.

Victoria produced 1,499,695 pounds of refined copper in 1915, which is 13,453 pounds better than for the year 1914. No large increase was possible, owing to the limited capacity of the hoist and shaft and the necessary work on the new shaft. The new shaft and the new hoist will more than double the present hoisting capacity. The net profit for the year was $45,799.80.

On May 16, 1915 wages were again restored to the former scale paid before the reduction in September 1914.

Little development work was done during 1915, due to the low stage of water the first part of the year and the fact that attention was directed to raising the new compartment of the shaft the latter part of the year. In the last six months of the year, however, the copper content of ore was at least one pound per ton better than that of the past eighteen months.

Hoisting from the upper levels of the new compartment with a small temporary hoist, will probably begin in February 1916. This will increase tonnage as well as development, and, at the same time, raise the copper content per ton and decrease the cost of production.

White Pine Copper Company.

Mine location: White Pine, Porcupine Mountain District, Ontonagon county.
General Manager: James MacNaughton.
Superintendent: Thomas H. Wilcox.
Controlled by the Calumet & Hecla Mining Co.

Mining operations were carried on in 1915 at the No. 2 temporary vertical shaft and at the inclined shafts Nos. 3 and 4. The openings on the second level west of No. 2 shaft were rather poor. All other openings, when in the lode, showed fair to good values. Stoping was begun in April; about 16 per cent of the lode is left in place for stope pillars.

During the last eight months of the year 114,039 tons of ore was treated, yielding 2,824,145 pounds of refined copper, an average of 24.76 pounds per ton. The total cost per pound including construction was 16.64 cents.

The stamp-mill went into commission in April. The mill is making a recovery of approximately 67 per cent. The tailing losses are excessive, consisting partly of sulphides, but mostly of free flaky particles of native copper. The tailings are being saved and can be rehandled at a later date if it proves profitable to do so.

A railroad about one and three-quarters miles in length was built to connect the mine plant with the Chicago, Milwaukee and St. Paul Railroad.

A premium of ten per cent will be added to the wages of all employees for the first six months of 1916.

During 1915 there was expended for construction work $351,438.07.

White Pine ended the year with a balance of assets of $139,786.05.

White Pine Extension.

Mine location: S. E. ¼ of the N. E. ¼ of section 7, T. 50 R. 43.
Post-office: Ontonagon, Ontonagon county.
General Manager: Theo. Dengler.
Superintendent: Fred B. Close.

Operations of this new organization began about November 1, 1914, and were reviewed in the report on the Copper Industry for 1914 under the heading "Smith Explorations." The present company was organized in July 1915, and is now under the Stanton management.

The work during the last two months of 1914 was done in the S. E. ¼ of the S. E. ¼ of section 12, T. 50, R. 44. A test shaft was sunk 70 feet, a crosscut made into the formation for 40 feet and 15 feet of drifting

done. The results of this work were very favorable and extensive diamond drilling was planned for the year 1915.

Diamond drilling was started in the early spring of 1915 and during the year a large area of land was explored. This drilling was done in section 7, 50-43 and in sections 12, 13 and 14, 50-44.

The remarkable showing of copper in several of these drill cores and the very satisfactory assays warranted the sinking of a shaft to develop and mine this rich section of the copper district. The sinking of a shaft was started in the S. E. ¼ of the N. E. ¼ of section 7, 50-43. The shaft is vertical and is sinking in the footwall of Outer Conglomerate.

The Nonesuch formation on the property of the White Pine Extension has a thickness of 550 to 600 feet. The strike is about N. 56½° E., but to the eastward swings more to the east. The dip at the test shaft in section 12 is about 58°. The dip steepens towards the east; at the present sinking shaft it is about 80° to the southeast, and at the east end of the property it is practically vertical.

The Nonesuch formation is composed of gray to black shales and gray grits and sandstone. The upper part is chiefly brown shale; the lower sandstones are coarser and usually conglomeratic. The copper-bearing horizons are in the lower part of the formation and in the two lower shale belts. Between the shale belts there is a sandstone. Some of the shale is carbonaceous, and there is more copper in the darker beds. The values are principally sulphides, chalcocite, with some chalcopyrite and bornite.

The upper lode is a banded shale 20 feet thick. This is a fine silicious rock, and the copper occurs near the bottom of the shale belt where the shale is darker in color. This dark portion is about two feet thick.

Below the banded shale there is usually a thin grit, two to six feet in thickness. Below this grit is No. 1 shale, about six to twenty feet thick. Below the No. 1 shale is a coarse sandstone, No. 1, which varies in thickness from four to ten feet. Below this coarse sandstone is No. 2 shale, usually four to six feet thick. Below the No. 2 shale is No. 2 sandstone which grades down into the Outer Conglomerate. No. 1 and No. 2 sandstone are usually conglomeratic.

Crosscuts will be driven from the shaft to the copper-bearing portions of the formation. Plans are being considered for the erection of a mill in the near future.

Winona Copper Company.

Mine location: Winona, Houghton county.
Superintendent: R. R. Seeber.

Work at the Winona was resumed early in May, when unwatering of the mine was commenced. Some copper was produced in June and

since then production has been gradually increased to about 200,000 pounds of refined copper per month.

The tributing arrangement ran from October 15, 1914 to June 1, 1915, with satisfactory results to the company as well as to the tributors.

The total production of refined copper for 1915 was 1,722,638 pounds. The yield of copper per ton of ore stamped was 16.79 pounds. The average price of copper sold was 17.4 cents per pound, which includes two and one-half months' production of tributors in 1914.

King Philip No. 1 shaft-house, which was destroyed by fire two years ago, is being replaced. This work will probably be completed in May and will enable Winona to increase its output some 35 per cent.

Balance of assets Dec. 31, 1915 was $223,324.11.

Wolverine Copper Mining Company.

Mine location: Kearsarge, Houghton county.
Superintendent: Theo. Dengler.

Wolverine continued normal output. A total of 7,250,866 pounds of refined copper was produced during the year ending July 1, 1915. The yield per ton stamped was 18.23 pounds and the total cost per pound 8.43 cents. Sales of copper, however, were made while the copper market was low and only 12.81 cents per pound was received. One dividend, amounting to $240,000.00, was paid in April.

About 44.6 per cent of the total ore hoisted was obtained with Jack-hammer machines, cutting out along the foot in old and more recent stopes. Openings during the year showed fair mineralization, but much of the ground will require selection underground.

Supt. Dengler states that "the condition of the property both on surface and underground, as well as at the mill, make it reasonable to assume that operations for the coming year will show little change as compared with the past fiscal year."

Wyandot Copper Company.

Mine location: Winona, Houghton county.
Superintendent: Frank L. Van Orden.

Work at the Wyandot was resumed April 6, 1915. The mine wa unwatered and actual mining started early in July. Drifts were extended north and south on the 9th level. The shaft was sunk to the 10th level and drifting taken up at that point. The results of the stoping were very encouraging and there is now a stockpile of about 2,000 tons which should yield very good returns.

The stoping has demonstrated that the mineralization is not confined

to a narrow zone immediately adjacent to the footwall of the lode but is found in places to be 16 feet wide. The ore is very rich in places.

A stamp-mill test of the stockpile will be made in the spring of 1916, and if the mill test meets present expectations the winze will be converted into a permanent shaft, making a surface connection through the overburden by means of a three-compartment vertical drop shaft.

Treasury assets, including cash and assessments due, are sufficient to continue development work along present lines for another two years.

SUMMARY OF FINANCIAL STATEMENTS OF MICHIGAN COPPER MINING COMPANIES FOR 1915.

	Balance of Assets (+), Liabilities (−). December 31, 1914.	Receipts.		Received in Assessments.	Paid in Dividends.	Balance of Assets (+), Liabilities (−). December 31, 1915.
		Sale of Copper.	Sale of Silver.			
Adventure	+$2,054 58					+$2,245 10
Ahmeek	+968,771 98	$3,985,061 98	$14,026 50		$1,650,000 00	+1,583,654 13
Algomah	+14,597 64	900 90				−18,133 65
Allouez	+363,822 85	1,824,534 07	35,032 12		200,000 00	+963,810 83
Atlantic	+231,330 39					+246,329 89
Bohemia	[1] +129,454 44					
Baltic	+490,550 85	2,093,525 52				+1,440,516 25
Calumet & Hecla	+6,902,866 46				5,000,000 00	+8,256,445 92
Centennial	+24,634 69	425,964 21				+273,118 50
Champion	+1,206,819 44	5,814,279 21			3,100,000 00	+1,815,868 46
Cherokee	+44,065 98					+39,791 62
Cliff	+36,379 30					+24,113 49
Contact	+4,703 36					+18,948 96
Copper Range Consolidated	+1,105,226 21	9,352,846 00			1,182,003 00	+3,390,463 21
Franklin	+117,165 81	156,068 16				+30,022 43
Gratiot	−400,833 59					
Hancock		82,379 31		$192,787 00		
Houghton	−7,650 05	9,875 98		71,524 00		+24,763 49
Indiana	−29,532 51			80,000 00		+14,574 35
Isle Royale	+199,815 69	1,715,251 08	38,973 56			+414,524 88
La Salle	+110,158 74	142,587 00	6,034 90			+94,636 49
Lake	+167,145 22	318,581 72		7,686 00		+254,164 08
Laurium	−14,657 14					−19,312 88
Mass	+45,887 12	851,739 84				+213,361 07
Mayflower	+55,115 64			12,454 00		+52,990 74
Michigan	−156,172 13	411 60		76,727 00		−117,907 16
Mohawk	+852,208 98	2,700,843 19			600,000 00	+1,763,784 71
New Arcadian	+10,431 95	14,143 69		117,463 75		+66,742 93
New Baltic	+869 50			23 754 60		+20,360 92
North Lake	+18,946 84					−15,556 20

SUMMARY OF FINANCIAL STATEMENTS OF MICHIGAN COPPER MINING COMPANIES FOR 1915.—*Concluded.*

	Balance of Assets (+), Liabilities (−). December 31, 1914.	Receipts.		Received in Assessments.	Paid in Dividends.	Balance of Assets (+), Liabilities (−). December 31, 1915.
		Sale of Copper.	Sale of Silver.			
Old Colony	+$56,971 80			$15,982 00		[2]+$35,666 75
Onondaga						[3]+46,585 10
Osceola	+1,613,436 31	$3,589,604 89			$1,057,650 00	+2,166,646 51
Pacific	+26,087 56					+26,939 36
Quincy	+897,531 77	3,972,129 42	$11,829 08		880,000 00	+1,664,956 46
Seneca	−166,939 51					−179,702 84
South Lake	−3,790 64	10,120 19				[4]+16,958 11
St. Mary's	+115,929 69				1,280,000 00	+289,544 32
Superior	+216,872 76	700,820 19	19,404 78			+216,274 86
Tamarack	+895,993 22	742,733 14				+1,204,980 94
Trimountain	+503,397 61	1,445,041 27				+1,158,144 13
Union Copper	+1,169 84					+13,745 45
Victoria	+40,624 36	193,305 49		25,766 00		+112,280 45
White Pine	−134,559 74	518,318 84				[5]+139,786 05
Winona	+92,648 62	185,036 74		18,481 00		+223,324 11
Wolverine	+829,109 29	929,192 60			360,000 00	[6]+787,310 67
Wyandot	+12,205 94			43,230 00		[7]+23,733 04
Total	$17,490,867 12	$41,775,296 23	$125,300 94	$685,855 35	$15,309,653 00	$28,781,496 03

[1]For year ending April 30, 1916.
[2]For year ending Sept. 30, 1915.
[3]For year ending Jan. 31, 1916.
[4]2,081 shares of stock were sold for $8,324.00 for non-payment of assessment, and 20,000 shares were sold at $5.00 per share.
[5]$461,500.00 received from sale of 18,460 shares of preferred stock at par ($25) per share.
[6]For year ending June 30, 1915.
[7]For year ending March 31, 1916.

SUMMARY OF RESULTS OBTAINED BY MICHIGAN COPPER MINING COMPANIES IN 1915.[2]

	Tons of ore treated.	Cost of mining, transportation, and stamping per ton.	Pounds of concentrate obtained.	Pounds of refined copper produced.	Per cent of refined copper in concentrate.	Pounds of refined copper per ton of ore treated.	Cost per pound at mine excluding construction.	Cost per pound, construction.	Cost per pound smelting, freight, commission and eastern office.	Other costs per pound.	Cost per pound interest paid.	Total cost per pound.	Price received for copper sold.
Ahmeek	948,874	$1.26	32,292,325	21,800,492	67.50	23.0	5.48c	0.81c	1.67c			7.96c	18.28c
Allouez	534,705	1.365	14,506,440	10,043,459	69.23	18.78	7.27c	0.19c	1.84c		0.01c	9.31c	18.166c
Baltic	378,443	2.73		12,028,947		31.79	8.13c		0.92c	0.45c		9.50c	17.40c
C. & H. (all ore)[1]	3,188,583	1.71		71,030,518		22.28		0.47c				9.33c	18.11c
C. & H. (Conglomerate)	1,739,984	2.13		51,738,588		29.74						8.69c	
C. & H. (Osceola lode)	1,448,599	1.07		19,291,930		13.32						9.71c	
Centennial	150,191	1.753	3,029,880	2,347,500	77.48	15.63	11.21c		1.16c		0.08c	12.45c	18.145c
Champion	923,743	1.95		33,417,599		36.17	5.12c		0.90c	0.28c		6.30c	17.40c
Franklin	122,018			1,314,969									19.83c
Hancock				871,124									18.57c
Houghton	14,656.92		285,900	156,766		10.69							22.2c
Isle Royale	680,270	1.45	13,727,832	9,342,106	68.05	13.7	10.56c	1.50c	2.06c	0.60c	0.22c	14.94c	18.36c
Lake	59,848		2,511,216	1,581,071	62.96	26.42							20.149c
La Salle	80,959			782,493		9.67							18.22c
Mass	323,335		7,105,295	4,638,452	65.28	14.35	13.06c	0.40c	1.31c			14.77c	18.363c
Mohawk	829,789	1.20	20,705,600	15,882,914	76.749	19.15	6.24c	0.27c	0.97c			7.48c	17.0c
New Arcadian	3,845			79,209		20.62							17.856c
Osceola	1,361,089	1.18	26,777,790	19,731,472	73.686	14.5	8.17c	0.41c	1.44c		0.01c	10.03c	18.19c
Quincy	1,269,000		34,251,765	22,054,813									18.0c
South Lake	3,993½			61,637		15.4							
Superior	212,051	1.88		3,866,484		18.23	10.31c		1.91c		0.07c	12.29c	18.125c
Tamarack	217,027	2.52	6,139,824	3,888,150	63.33	17.9	14.04c	0.82c	2.11c		0.10c	17.07c	19.10c
Trimountain	349,684	2.02		8,302,896		23.75	8.38c		1.00c	0.14c		9.52c	17.40c
Victoria	133,984		2,262,244	1,499,695									
White Pine	114,039	2.182		2,824,145		24.76	8.80c	5,64c	2.04c		0.16c	16.64c	18.353c
Winona	102,594.05		3,032,045	1,722,638		16.79							17.4c
Wolverine (1914-15)	397,614	1.30	9,734,850	7,250,866	74.48	18.23	7.13c		1.30c			8.43c	12.81c
Total	15,529,070.47		173,851,850	325,969,862									

[1]1,582,802 pounds was recovered by the C. & H. from the sand bank at Torch Lake.
[2]For production of Michigan Copper Mines in prior years see Publication 19, Geological Series 16, Mich. Geol. Survey, 1915.

IRON INDUSTRY,

STATISTICAL TABLES.

IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.[7]

Name of Mine.	1906 and prior years.	1907.	1908.	1909.
American (Sterling)	113,349	13,764	23,222	90,001
Ames	6,298			
Barnum (Cliff Shaft)[1]	801,851			
Bay State	16,637			
Bessemer (See Lillie)				
Bessie	59,097			
Beaufort (Ohio)	354,654	78,029	61,035	72,987
Blue (See Queen Group)				
Boston (with American)	62,542			
Braastad { Mitchell	136,636			
Braastad { Winthrop	831,445			
Breitung No. 1				
Breitung Hamatite No. 2	101,394	59,667	55,849	129,673
Buffalo[2]	217,730			
Cambria	1,679,780	135,145	85,977	136,815
Champion	4,275,296	107,577	313	11,199
Chase				
Chester (See Rolling Mill)				
Chicago	9,012			
Cleveland[3]	2,806,298			
Cleveland Hematite (Included under Cleveland)				
Cleveland Cliffs Group[4]	12,893,166	1,030,928	438,379	877,433
Columbia (Kloman)	94,813			
Curry	16,671			
Dalliba (Phoenix)	59,114			
Detroit	140,841			
Dexter	118,512			
Dey	2,709			
East Champion	76,002			
East New York	327,604			
Edison	893			
Edwards (See Sampson)				
Empire		40,565	53,537	108,993
Erie	8,136			
Etna	1,091			
Fitch	31,817			
Foster[5]	171,893			
Foxdale	31,447			
Gibson	16,357			
Goodrich	49,754			
Grand Rapids (Davis)	110,736			
Green Bay (See Bay State)				
Hartford	909,744	328,161	278,366	250,680
Himrod				
Holmes				
Hortense (North Champion)	30,574			
Home (P. and L. S.) (Now Volunteer)	26,022			
Humboldt (Washington)	713,961			
Imperial	157,226	55,756	48,231	115,478
Indiana (See Bay State)				
Iron Cliffs[6]	1,700,537			
Iron Mountain	393			
Isabella				
Jackson	3,807,108	61,345		11,060
Keystone (See East Champion)				
Lake[10]				
Lake Angeline	7,501,378	283,373	220,410	280,298
Lake Superior	13,646,107	674,066	261,955	349,435
Lillie	1,597,605	80,545	8,632	61,708
Loyd				
Lucy (McComber)	516,244		1,115	1,672
Maas		32,378	29,036	159,197
Magnetic (Stock Pile)	292			
Manganese (Negaunee)	6,359			

See foot notes 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 on page 62.

IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.

1910.	1911.	1912.	1913.	1914.	1915.	Total.
163,290	195,197	122,211	162,253	84,845	87,514	1,055,646
						6,298
						801,851
						16,637
						59,097
23,427	2,683				21,139	613,954
						62,542
						136,636
						831,445
	63,497	57,085	30,994	49,590	[1]74,107	275,273
114,202	72,688	63,995	83,280	27,705	[2]76,620	785,073
						217,730
150,422	85,954	69,904	169,153	132,834	159,443	2,805,427
18,746						4,413,131
			52,930	19,708	39,059	111,697
						9,012
						2,806,298
955,374	514,305	1,032,836	922,005	672,428	[3]631,358	19,968,212
						94,813
						16,671
						59,114
						140,841
						118,512
						2,709
						76,002
						327,604
						893
53,687	16,954	33,124	38,348			345,208
						8,136
						1,091
						31,817
						171,893
						31,447
						16,357
						49,754
						110,736
183,471						1,950,422
				14,466	[4]44,669	59,135
					17,373	17,373
						30,574
						26,022
						713,961
83,404	86,959	53,943	37,543			638,540
						1,700,537
					10,807	11,200
					[6]36,255	36,255
40,320	22,303	53,559	1,519	20,241	56,026	4,073,481
244,923	167,258	151,910	102,762	128,073	19,513	9,099,898
271,445	167,352	169,326	164,834	133,519	199,920	16,037,959
10,121	25,597	26,119				1,810,327
	28,003	44,224	135,746	123,211	195,975	527,159
11,257	16,676	72,724				619,688
208,103	24,926	46,664	171,475	55,903	267,190	994,872
						292
						6,359

See foot notes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 on page 63.

IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.[7]—*Concluded.*

Name of Mine.	1906 and prior years.	1907.	1908.	1909.
Marquette[7]	152,847			
Mary Charlotte	562,014	155,633	99,104	240,433
Mesabi's Friend	16,043			
Michigamme[6]	880,362			
Miller	4,756			
Milwaukee-Davis	375,451			
Mitchell	17,780		11,539	
Moore	68,131			
Morris				
National	150,216			
Negaunee	2,821,521	196,170	232,219	312,217
Negaunee Construction Works	12,708			
New York (York)	1,123,071			
New York Hematite	37,587			
North Champion (See Hortense)				
North Republic	289			
Nonpareil (St. Lawrence)	23,395			
Northwest	1,687			
Norwood	5,753			
Ogden	986			
Pascoe	59,806			
Pendill	45,993			
Palmer	14,172			
Palmer (Cascade) (See Volunteer)				
Pioneer	15,409			
Pittsburg & Lake Angeline (See Lake Angeline)				
Platt	73,844			
Portland				79,652
Primrose	6,040			
Prince of Wales[2]	32,415			
Quartz	491			
Queen[2]	180,866			
Queen Group[8]	4,664,474	309,917	104,098	237,509
Republic	5,778,341	170,554	67,999	176,575
Republic Reduction Co	47,174			
Richards	8,261			
Richmond	489,739	35,156	60,994	102,566
Riverside	16,160			
Rolling Mill	344,426	49,204	52,147	133,139
Saginaw	451,424			
Salisbury[6]	686,411			
Sam Mitchell (See Mitchell)				
Sampson (Argyle)	267,805			
Shadt	1,261			
Section 12	21,887			
South Buffalo[3]	245,412			
Spurr	165,244			
Star West (Wheat)	204,649			
St. Lawrence (See Nonpareil)				
Sterling (See American)				
Taylor	32,970			
Teal Lake (See Cambria)				
Titan	90,371			
Volunteer (See also Home)	1,383,153	10,022		
Washington			20,625	44,716
Webster	34,905			
West Republic	133,077			
Wetmore	50,870			
Wheeling	433,771			
Winthrop[9]	1,335,839			
Wheat (See Star West)				
Totals	79,808,382	3,907,955	2,214,782	3,983,436

See foot notes 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 on page 62.

IRON ORE SHIPMENTS FROM THE MARQUETTE RANGE.—*Concluded.*

1910.	1911.	1912.	1913.	1914.	1915.	Total.
						152,847
197,522	340,335	250,700	262,431	57,138	[8]159,817	2,325,127
						16,043
						880,362
						4,756
	7,781	11,536	10,310		6,572	411,650
23,428	21,387	21,141	15,970			111,245
						68,131
		1,529	18,394	29,063	80,546	129,532
						150,216
348,818	140,040	442,190	327,447	247,484	480,521	5,548,627
						12,708
						1,123,071
						37,587
						289
						23,395
						1,687
						5,753
						986
						59,806
						45,993
						14,172
						15,409
						73,844
49,584				45,324	[9]97,476	272,036
						6,040
						32,415
						419
						180,866
230,119	295,962	224,862	235,648	178,574	473,961	6,955,124
150,732	113,137	156,867	135,879	52,562	215,182	7,017,828
						47,174
						8,261
95,772	47,293	117,873	138,394	129,551	[8]177,304	1,394,642
						16,160
115,193	96,584	115,784	163,287	98,010	[10]130,900	1,298,674
						451,424
						686,411
						267,805
						1,261
						21,887
						245,412
						165,244
						204,649
						32,970
						90,371
	51,240	9,008	47,220	38,438	[11]18,851	1,557,932
96,769	62,010	66,540	60,171	1,659		352,490
						34,905
						133,077
						50,870
						433,771
						1,335,839
3,840,129	2,666,121	3,415,654	3,487,993	2,340,326	[12]3,778,098	109,442,876

See foot notes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 on page 63.

[1]Under Iron Cliffs 1890-1895; under Cleveland-Cliffs group after 1895.
[2]Under Queen group after 1890.
[3]Under Cleveland-Cliffs group after 1883.
[4]Includes Cleveland after 1883; includes Barnum, Foster, Iron Cliffs, Michigamme and Salisbury after 1895.
[5]Under Iron Cliffs 1891-1895; under Cleveland-Cliffs group after 1895.
[6]Under Cleveland-Cliffs group after 1895.
[7]Under Winthrop after 1892.
[8]Includes Buffalo, Prince of Wales, Queen and South Buffalo after 1890.
[9]Prior to 1890, see Braastad; includes Marquette after 1892.
[10]Included in Cleveland-Cliffs Group.

[1]Iron Trade Review reports 152,063 tons shipped in 1915 by Breitung Hamatite No. 1 and No. 2 combined.

[2]See foot note No. 1.

[3]Iron Trade Review reports 634,837 tons shipped in 1915.

[4]Iron Trade Review reports 203,922 tons shipped in 1915 by Mary Charlotte. Figure includes Himrod shipment.

[5]See foot note No. 4.

[6]Isabella shipment not reported by Iron Trade Review.

[7]Does not include Gwinn district. Does include west end of range in Baraga county.

[8]Iron Trade Review figure.

[9]Iron Trade Review reports 177,000 tons shipped in 1915.

[10]Iron Trade Review reports 130,902 tons shipped in 1915.

[11]Iron Trade Review reports 18,850 tons shipped in 1915.

Total for Marquette range 1915, Iron Trade Review, 3,746,591 tons. See foot note No. 7.

IRON ORE SHIPMENTS FROM THE GWINN DISTRICT. (GROSS TONS)

	1906 and prior years.	1907.	1908.	1909.
(Austin)		195,950	111,229	125,858
Gwinn				
(Princeton) (Swanzy or Chesire)	1,014,341	177,863	36,033	42,934
Stegmiller				39,869
(Stephenson)		6,305	52,588	64,075
Total	1,014,341	380,118	199,850	272,736

IRON ORE SHIPMENTS FROM THE GOGEBIC RANGE, MICHIGAN.

	1906 and prior years.	1907.	1908.	1909.
Ada (included in Ironton)				
Anvil and North Anvil	622,913	39,495	35,937	22,927
Ashland	4,569,877	298,056	259,611	259,612
Asteroid				
Aurora (Norrie-Aurora Group after 1904)	3,961,684			
Bessemer	20,889			
Blue Jacket	1,799			
Brotherton	1,448,408	104,224	96,776	103,090
Castile	2,108	6,157		26,982
Chicago	68,727			
Colby	2,127,468	94,480	58,305	170,095
Davis (Wisconsin)	103,961			
Eureka	166,244	57,904	122,324	115,662
Federal	36,443			
First National	1,997			
Geneva	7,108			
Imperial (See Federal)				
Iron Chief	12,199			
Iron Chief No. 2	551			
Iron King (See Newport)				
Ironton	288,391	190,968	92,932	277,594
Jack Pot	99,090			
Meteor (Comet)	216,367			
Mikado	647,382	163,891	86,617	99,195
New Davis (See Davis)				
Newport and Bonnie	3,705,799	551,496	579,390	1,008,354
Norrie-Aurora Group (after 1904)	14,885,276	1,109,085	773,243	977,054
Pabst (Norrie-Aurora Group)	2,366,583			
Palms	1,284,489			
Pike	45,333	24,922	6,303	22,174
Puritan (Ruby)	109,572			
Royal				
Section 13				
South Chicago				
Sparta	4,862			
Sunday Lake	1,000,234	101,899	111,130	93,712
Tilden	4,510,449	312,496	111,184	154,506
Vaughn (See Aurora) (Norrie-Aurora Group after 1904)				
Wakefield				
Wisconsin (See Davis)				
Yale (West Colby)	248,831	38,010	14,874	71,458
Total	42,565,034	3,093,083	2,348,626	3,402,415

[1]Iron Trade Review.
[2]Iron Trade Review reports 112,932 tons shipped 1915. This figure includes 17,692 tons shipped from the Minnewawa (Wisconsin).
[3]Iron Trade Review reports 1,408,516 tons shipped 1915.
[4]Iron Trade Review reports 838,875 tons shipped 1915.
[5]Iron Trade Review reports 442,422 tons shipped 1915.

IRON ORE SHIPMENTS FROM THE GWINN DISTRICT. (GROSS TONS)

1910.	1911.	1912.	1913.	1914.	1915.	Total.
188,588	110,839	102,530	107,365	30,493		972,852
	230			20,159	57,910	78,299
89,441	54,442	143,519	53,479	13,607	[8]17,171	1,642,830
48,842	45,122	50,963	45,431	40,972	40,272	311,471
225,726	135,474	214,386	96,298	93,796	243,458	1,132,106
552,597	346,107	511,398	302,573	199,027	358,811	4,137,558

IRON ORE SHIPMENTS FROM THE GOGEBIC RANGE, MICHIGAN.

1910.	1911.	1912.	1913.	1914.	1915.	Total.
7,235	310	55,610	238	5,771	[7]44,749	835,185
231,506	151,478	211,927	2,635	123,702	[2]94,622	6,203,026
	20,569	70,239	42,419	135,120	13,468	281,815
						3,961,684
						20,889
						1,799
102,626	65,015	148,930	70,138	47,662	107,244	2,294,113
20,197	23,597	136,703	57,595	36,569	[6]75,596	385,504
					[1]30,977	99,704
194,754	41,673	245,195	305,744	291,947	315,913	3,845,574
						103,961
41,611	98,609	65,723	14,562	23,430	128,414	834,483
						36,443
						1,997
			31,303		34,416	72,827
						12,199
						551
109,025	63,359	173,135	166,123	51,138		1,412,665
						99,090
						216,367
52,715			33,111	2,094	1,044	1,086,049
					5,434	5,434
1,182,324	555,853	966,435	1,139,666	702,861	[4]835,058	11,227,226
1,333,006	883,910	1,500,758	1,503,451	985,199	[3]1,407,770	25,358,752
						2,366,583
		39,152	88,644	173,792	[5]444,673	2,030,750
3,324						102,056
50,019		90,683	64,463	58,410	80,367	453,514
			10,659	11,686	8,004	30,349
			3,844		32,356	36,200
					[1]1,274	1,274
						4,862
115,486	56,096	155,485	110,374	54,327	136,211	1,934,954
99,937	138,387	158,191	97,686	114,777	99,516	5,797,129
			15,261	313,050	651,302	979,613
108,253	154,944	76,772	89,482	19,074	42,632	864,330
3,652,918	2,253,800	4,094,938	3,847,398	3,150,609	4,591,040	72,998,961

[6]Iron Trade Review reports 76,702 tons shipped 1915.
[7]Iron Trade Review reports 45,171 tons shipped 1915.
[8]Iron Trade Review reports 40,248 tons shipped 1915.
Total for Gogebic range 1915 Iron Trade Review 4,595,498 tons.
Total for Gwinn district 1915 Iron Trade Review 358,787 tons.

IRON ORE SHIPMENTS FROM THE MENOMINEE DISTRICT, MICHIGAN.

	1906 and prior years.	1907.	1908.	1909.
Antoine	1,252,796	100,996	....	....
Aragon	4,921,305	441,636	226,354	246,984
Breen	55,059	20,366	....	....
Briar Hill	14,981	....	....	....
Chapin	14,347,841	855,308	391,620	587,647
Clifford & Traders	....		....	103,626
Cornell	49,302	....	....	....
Cuff	58,419	....	....	....
Cundy	807,967	....	1,410	5,512
Curry	416,928	....	....	....
Cyclops	286,093			
Eleanor (Appleton)	17,042	1,677	....	....
Emmett	66,655	....	....	....
Forest	11,988	....	....	....
Half and Half	7,524	....	....	....
Hamilton	96,072	....	....	....
Hersel	955	....	....	....
Indiana	17,871	....	....	....
Keel Ridge	93,101	....	....	....
Loretto	985,274	99,779	13,354	96,613
Ludington	1,001,518	....	....	....
Millie (Hewitt)	335,365	18,691	3,322	10,887
Munro	180,708	46,834	27,773	23,241
Norway	1,291,352	....	....	....
Penn Iron Mining Co	3,852,005	381,128	176,211	428,004
Perry	3,138	....	....	....
Pewabic	5,629,150	457,796	365,341	465,453
Quinnesec	499,756	....	....	3,147
Saginaw (Perkins)	417,242	26,080	38,669	19,994
Stephenson	39,350	....	....	....
Sturgeon River	19,404	....	....	....
Verona	130,975	....	....	....
Vivian	346,863	48,493	10,056	....
Vulcan (with Penn Mines)	1,668,654	....	....	....
Walpole	19,089	....	....	....
Total	38,971,702	2,498,784	1,254,110	1,991,108
Metropolitan Trough.				
Groveland	26,123	13,913	9,123	24,933
Metropolitan	107,027	....	....	....
Northwestern	35,810	....	....	....
Total	168,960	13,913	9,123	24,933
Calumet Trough.				
Calumet	54,486	51,646	15,222	....

IRON ORE SHIPMENTS FROM THE MENOMINEE DISTRICT, MICHIGAN.

1910.	1911.	1912.	1913.	1914.	1915.	Total.
....	....	....	....	....	....	1,353,792
241,046	201,269	244,812	230,958	188,765	302,275	7,245,404
....	....	....	....	....	....	75,425
....	....	....	....	....	....	14,981
465,543	357,598	327,999	369,822	341,493	[1]385,174	18,430,015
91,081	90,940	74,144	95,311	66,329	....	521,431
....	....	....	....	....	....	49,302
....	....	....	....	....	....	58,419
....	....	....	....	....	....	844,889
....	....	....	....	....	....	416,928
....	....	....	....	....	....	286,093
....	....	....	....	....	....	18,719
....	....	....	....	....	....	66,655
....	....	....	....	....	....	11,988
....	....	....	....	....	....	7,524
....	....	....	....	....	....	96,072
....	....	....	....	....	....	955
....	....	....	....	....	52,570	70,441
....	....	....	....	....	....	93,101
116,048	18,579	135,177	158,257	45,449	68,806	1,737,336
....	....	....	....	....	....	1,001,518
....	18,556	....	....	361	....	387,182
20,022	9,303	20,100	18,509	....	....	346,490
....	....	....	....	....	....	1,291,352
344,760	377,026	426,743	416,410	214,827	[2]368,451	6,985,565
....	....	....	....	....	....	3,138
380,376	352,598	279,771	364,176	299,228	178,013	8,771,862
744	....	....	....	....	....	503,647
....	....	....	....	....	....	501,985
....	....	....	....	....	....	39,350
....	....	....	....	....	....	19,404
....	....	....	....	....	....	130,975
14,827	5,971	28,800	27,177	....	....	482,187
....	....	....	....	....	....	1,668,654
....	....	....	....	....	....	19,089
1,674,447	1,431,840	1,537,546	1,680,620	1,156,452	1,355,289	53,551,898
26,462	33,758	12,468	9,251	....	....	156,031
....	....	....	....	....	....	107,027
....	....	....	....	....	....	35,810
26,462	33,758	12,468	9,251	....	....	298,868
....	....	35,587	18,976	....	....	175,917

[1]Iron Trade Review reports 384,654 tons shipped 1915.
[2]Iron Trade Review reports 411,393 tons shipped 1915.
Total for Menominee range 1915 Iron Trade Review 1,397,711 tons.

IRON ORE SHIPMENTS FROM THE CRYSTAL FALLS DISTRICT, MICHIGAN.

	1906 and prior years.	1907.	1908.	1909.
Alpha	1,370			
Armenia	274,943	36,665		
Balkan				
Bristol (Claire)	1,252,566	345,676	196,300	396,825
Carpenter				
Columbia	942,703			
Crystal Falls	1,619,811	114,158	296	986
Delphic	33,770			
Dunn	1,177,654	141,992	8,829	193,396
Fairbanks	8,500			
Genesee (Ethel)	366,870	38,984		65,585
Gibson	16,357		4,548	36,246
Great Western	1,400,744	234,492	124,246	112,747
Hemlock	1,276,322	117,181	83,834	112,481
Hilltop	20,229			
Hollister	4,098	6,371	10,671	25,842
Hope	28,530			
Judson				
Kimball		16,224		
Lamont (Monitor)	513,251	42,090		
Lee Peck	2,844			
Lincoln	239,256	714		1,657
Magnate	6,844			
Mansfield	756,120	183,532	44,633	118,713
Mastodon	425,708			
McDonald				1,114
Michigan	113,365	39,819	603	
Monongahela	9,310			
Paint River (Fairbanks)	295,484	75,805		
Ravenna				
Richards				
Sheldon & Shafer (Union) (See Columbia)				
South Mastodon	8,203			
Tobin	635,646	237,781	161,642	359,668
Warner				
Youngstown	151,425			
Total	11,581,923	1,631,484	629,602	1,425,261

IRON ORE SHIPMENTS FROM THE CRYSTAL FALLS DISTRICT, MICHIGAN.

1910.	1911.	1912.	1913.	1914.	1915.	Total.
						1,370
65,473	51,862	150,808	83,202	50,501		713,454
					[5]144,284	144,284
270,742	322,729	438,900	379,169	172,006	[1]378,831	4,147,744
				51,147	[2]284,187	335,334
						942,703
						1,735,251
						33,770
136,144	232,092	242,304	61,080	52,883	8,304	2,254,678
						8,500
66,185	25,342	4,248			1,184	568,398
45,202	56,528					158,881
80,709	84,338	3,342	50,464		35,759	2,126,840
115,407	107,753	126,132	113,201	46,449	[6]28,172	2,126,932
				8,223		28,452
49,434	5,022		25,251	16,430		143,119
						28,530
				6,619		6,619
					19,533	35,757
3,183						558,524
						2,844
						241,627
						6,844
114,357	54,646		190,503			1,462,504
						425,708
6,022	5,240	1,384	16,499			30,259
17,922			27,917	9,471	[6]112,721	321,828
						9,310
						371,289
	127	18,303	70,766	49,308	[3]116,735	255,239
				7,069	92,807	99,876
						8,203
235,812	308,456	319,318	154,896	65,351	18,624	2,497,194
					[4]46	46
						151,425
1,206,592	1,254,135	1,304,739	1,172,948	535,457	1,241,187	21,083,336

[1]Iron Trade Review reports 378,786 tons shipped 1915.
[2]Iron Trade Review reports 284,088 tons shipped 1915.
[3]Iron Trade Review reports 116,724 tons shipped 1915.
[4]Not reported by Iron Trade Review.
[5]Not reported by Iron Trade Review.
[6]Iron Trade Review reports Hemlock 28,172 tons, Michigan 112,680 tons shipped 1915.
Total for Crystal Falls district 1915 Iron Trade Review 1,240,946 tons.

IRON ORE SHIPMENTS FROM THE IRON RIVER DISTRICT, MICHIGAN.

	1906 and prior years.	1907.	1908.	1909.
Baker	....	....	....	45,003
Baltic	676,081	189,119	129,037	174,426
Bates	....	....	....	....
Bengal	....	....	....	....
Berkshire	....	....	3,440	34,295
Beta	4,211	....	....	....
Caspian	97,453	138,867	102,628	189,023
Cortland	....	....	....	....
Cottrell	....	....	....	....
Chatham-Riverton	....	14,883	45,826	68,730
Davidson No. 1	....	....	....	....
Davidson No. 2	....	....	....	....
Chicagon	....	....	....	....
Fogarty	....	7,949	32,560	77,356
Forbes	....	....	....	....
Hiawatha	210,683	....	138,190	136,739
Homer	....	....	....	....
Iron River	904,587	....	....	....
James (Osana)	....	2,360	59,760	90,851
*Dober-Isabella	65,192	....	....	....
Nanaimo	319,682	53,778	305	....
Riverton (Dober and Isabella)	832,467	90,358	47,073	171,200
Rogers	....	....	....	....
Selden	2,092	....	....	....
Sheridan	116,299	....	....	....
Tully	....	....	....	....
Virgil	....	....	....	....
Warner	....	....	....	....
Wauseca	....	....	....	....
Wickwire	....	....	....	....
Youngs	58,509	92,632	70,094	154,150
Zimmerman	....	....	1,832	10,303
Total	3,287,256	589,946	630,745	1,152,076

*Riverton.

IRON ORE SHIPMENTS FROM THE IRON RIVER DISTRICT, MICHIGAN.

1910.	1911.	1912.	1913.	1914.	1915.	Total.
39,417	3,290	....	24,286	113,733	41,378	267,107
171,930	66,502	100,736	130,631	29,206	10,078	1,677,746
....	....	....	....	....	45,171	45,171
....	....	....	23,259	5,539	39,615	68,413
97,999	22,272	33,422	....	23,826	15,413	230,667
....	....	....	....	....	....	4,211
171,334	165,660	306,914	295,841	279,379	479,083	2,226,182
....	....	17,499	26,823	15,316	....	59,638
....	....	....	....	....	45	45
51,988	58,054	135,298	107,604	19,455	[1]132,664	634,502
....	215	27,614	115,499	70,881	86,103	300,312
....	45,219	98,760	79,948	51,686	66,327	341,940
....	108,947	149,619	137,002	114,849	[2]155,411	665,828
51,071	67,616	84,074	124,568	15,329	27,718	488,241
....	....	....	69,435	77,960	[3]99,219	246,614
128,884	116,633	220,106	160,511	91,370	93,453	1,296,569
....	....	....	....	....	102,511	102,511
....	....	....	....	....	....	904,587
78,388	50,439	75,702	176,634	73,832	102,294	710,260
....	....	....	....	....	....	65,192
....	....	....	....	....	....	373,765
84,269	200,142	171,493	160,818	176,274	262,382	2,196,476
....	....	....	....	27,081	53,155	80,236
....	....	....	....	....	....	2,092
....	....	....	....	....	....	116,299
2,726	8,323	....	16,650	63,411	242,049	333,159
....	....	3,750	48,395	5,972	....	58,117
....	....	....	....	....	46	46
....	749	....	12,377	....	19,361	32,487
....	1,919	40,417	40,322	25,584	....	108,242
98,399	89,450	83,528	43,649	....	....	690,411
25,555	110,084	187,584	149,309	172,720	108,218	765,605
1,001,960	1,115,514	1,736,516	1,943,560	1,453,403	2,181,694	15,092,670

[1]Iron Trade Review reports 132,779 tons shipped 1915.
[2]Iron Trade Review reports 155,711 tons shipped 1915.
[3]Iron Trade Review reports 99,050 tons shipped 1915.
Total for Iron River district 1915, Iron Trade Review 2,182,934 tons.

SUMMARY OF IRON ORE SHIPMENTS FROM MICHIGAN RANGES. (GROSS TONS.)

	1902 and prior years.	1903.	1904.	1905.	1906.
Marquette	66,118,824	2,956,022	2,767,242	4,086,943	3,935,293
Gwinn	558,684	84,223	76,461	129,079	166,894
Menominee	29,034,583	2,528,819	1,712,800	2,741,169	2,953,131
Crystal Falls	7,269,225	824,461	917,969	1,174,366	1,395,910
Iron River	1,819,306	276,785	284,273	337,973	568,469
Gogebic	32,090,545	2,465,263	2,042,398	3,215,352	3,113,981
Metropolitan	145,749	18,574	4,737	....	....
Calumet	38,913	....	....	....	15,773
Total	137,075,729	9,154,147	7,805,880	11,684,432	12,149,451

	1907.	1908.	1909.	1910.	1911.
Marquette	3,907,955	2,214,782	3,983,436	3,840,129	2,614,881
Gwinn	380,118	199,850	272,736	552,597	346,104
Menominee	2,498,784	1,254,110	1,991,108	1,674,447	1,431,840
Crystal Falls	1,631,484	629,602	1,425,261	1,206,592	1,254,135
Iron River	589,946	630,745	1,152,076	1,001,960	1,115,514
Gogebic	3,093,083	2,348,626	3,402,415	3,652,918	2,102,322
Metropolitan	13,913	9,123	24,933	26,462	33,758
Calumet	51,646	15,222	....	....	....
Total	12,166,929	7,302,060	12,251,965	11,955,105	8,898,554

	1912.	1913.	1914.	1915.	Total.
Marquette	3,406,646	3,487,993	2,340,326	3,778,098	109,442,876
Gwinn	510,398	302,573	199,027	358,811	4,137,558
Menominee	1,538,746	1,680,620	1,156,452	1,355,289	53,551,898
Crystal Falls	1,304,739	1,172,948	535,457	1,241,187	21,983,336
Iron River	1,736,966	1,943,560	1,453,403	2,181,694	15,092,670
Gogebic	3,883,011	3,847,398	3,150,609	4,591,040	72,998,961
Metropolitan	12,468	9,251	....	....	298,868
Calumet	35,387	18,976	....	....	175,917
Totals	12,428,361	12,463,319	8,835,274	13,506,119	277,682,084

SHIPMENTS OF IRON ORE FROM MICHIGAN RANGES BY COUNTIES.
(GROSS TONS.)

County.	1902 and prior years.	1903.	1904.	1905.	1906.
Gogebic	32,090,545	2,465,263	2,042,398	3,215,352	3,113,981
Iron	9,088,531	1,101,246	1,202,242	1,512,339	1,964,379
Dickinson	29,219,145	2,547,393	1,717,537	2,741,169	2,968,904
Marquette	66,057,163	2,905,597	2,817,195	4,175,605	4,097,111
Baraga	610,345	134,648	26,508	39,967	5,076
Total	137,075,729	9,154,147	7,805,880	11,684,432	12,149,451

County.	1907.	1908.	1909.	1910.	1911.
Gogebic	3,093,083	2,348,626	3,402,415	3,652,918	2,102,322
Iron	2,221,430	1,260,347	2,577,337	2,208,552	2,369,649
Dickinson	2,564,343	1,278,455	2,016,041	1,700,909	1,465,598
Marquette	4,154,288	2,305,366	3,888,055	4,236,311	2,871,116
Baraga	133,785	109,266	368,117	156,415	89,642
Total	12,166,929	7,302,060	12,251,965	11,955,105	8,898,327

County.	1912.	1913.	1914.	1915.	Total.
Gogebic	3,883,011	3,836,739	3,150,609	4,591,040	72,998,961
Iron	3,041,705	3,116,508	1,988,860	3,422,881	37,076,006
Dickinson	1,585,601	1,708,847	1,156,452	1,355,289	54,026,683
Marquette	3,864,101	3,753,023	2,494,029	4,018,294	111,613,697
Baraga	53,943	37,543	45,324	118,615	1,966,737
Total	12,428,361	12,452,660	8,835,274	13,506,119	277,682,084

LIST OF THE ACTIVE IRON MINES OF MICHIGAN

Name of mine.	Location.				First shipment.	No. of men employed 1915.	Depth, 1915. Feet.
	County.	Section.	Twp.	Rge.			
MARQUETTE RANGE:							
American and Boston	Marquette	32	48	28	1880	313	1,620
Breitung Hematite No. 1	Marquette	8	47	26	1903	148	585
Breitung Hematite No. 2	Marquette	8	47	26	......	73	640
Cambria	Marquette	35	48	27	1875	123	978
Champion	Marquette	31,32	48	29	1867	Idle	1,984
Chase	Marquette	3	47	28	1913	22	351
Cliff Shaft	Marquette	9,10	47	27	1887	300	987
Empire	Marquette	19	47	26	1907	Idle	200
Gwinn	Marquette	28	45	25	1914	169	1,009
Hartford (Cambria No. 2)	Marquette	36	48	27	1889	......	......
Himrod	Marquette	7	47	26	1914	60	435
Imperial	Baraga	25	48	31	1890	Idle	185
Isabella	Marquette	29,32	47	26	1915	94	702
Jackson	Marquette	1	47	27	1846	25	208
Lake and Moro	Marquette	10	47	27	1892	260	591
Lake Sally	Marquette	14	47	27	1915	30	†
Lake Superior (Hard Ore)	Marquette	9,10	47	27	1858	221	1,080
Lake Superior (Soft Ore)	Marquette	10	47	27	1858	32	820
Lake Angeline	Marquette	15	47	27	1864	*	615
Lloyd (see Morris)	Marquette	6	47	27	1911	......	808
Lucy (with Jackson)	Marquette	6,7	47	26	1878	......	281
Maas	Marquette	31	48	26	1907	87	1,100
Maitland (Volunteer)	Marquette	30	47	26	......	......	506
Mary Charlotte	Marquette	8	47	26	1903	127	640
Morris and Lloyd	Marquette	1	47	28	1912	262	800
Moro (with Lake)	Marquette	10	47	27	1881	......	......
Negaunee	Marquette	5,6	47	26	1887	266	1,086
Ohio	Baraga	22	48	31	1882	1	250
Portland	Baraga	26	48	31	1896	*	......
Queen Group	Marquette	5	47	26	1888	246	1,010
Republic	Marquette	7	46	29	1872	258	2,050
Richmond	Marquette	28	47	26	1896	49	......
Rolling Mill	Marquette	7	47	26	1872	140	786
Salisbury	Marquette	15	47	27	1872	37	709
Volunteer	Marquette	30	47	26	1871	43	505
Washington (Barron)	Marquette	11	47	29	1865	Idle	875
SWANZY DISTRICT:							
Austin	Marquette	20	45	25	1907	Idle	364
Princeton	Marquette	18,20	45	25	1872	17	782
Stegmiller	Marquette	17	45	25	1909	63	300
Stephenson	Marquette	20	45	25	1907	209	562
MENOMINEE RANGE:							
Aragon	Dickinson	8,9	39	29	1889	266	1,355
Chapin	Dickinson	25,30	40	31,30	1880	546	1,501
Cyclops & Norway (Penn Gr'p)	Dickinson	5	39	29	1878	......	355
East Vulcan (Penn Group)	Dickinson	10,11	39	29	1877	631	1,400
Indiana	Dickinson	27	40	30	1915	*	85
Loretto	Dickinson	7	39	28	1893	125	800
Millie (Hewitt)	Dickinson	31	40	34	1881	1	312
Munro	Dickinson	6	39	29	1903	1	170
Pewabic	Dickinson	32	40	30	1890	259	941
West Vulcan, Curry & Brier Hil	Dickinson	9,10	39	29	1879	......	1,770
Clifford and Traders	Dickinson	20	40	30	......	2	143

*Not reported.
†Undeveloped.

1915, WITH LOCATION, OWNERSHIP, ETC.

Number or name of level.	Operators.	Address of Home Office.
20th	American Boston Mining Co......	1300 Leader-News Building, Cleveland, Ohio.
9th	Breitung Hematite Mng. Co......	Marquette, Mich.
6th	Breitung Hematite Mng. Co......	Marquette, Mich.
5th	Republic Iron & Steel Co.........	Youngstown, Ohio.
33d	Champion Iron Co..............	Wolvin Building, Duluth, Minnesota.
3d	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
10th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
2d	Empire Iron Co.................	Rector Building, Chicago, Illinois.
8th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
....	Republic Iron & Steel Co.........	Youngstown, Ohio.
4th	Mary Charlotte Mng. Co.........	Marquette, Mich.
4th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
1st	Cascade Mining Co..............	Hibbing, Minn.
....	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
5th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
....	Jones & Laughlin Ore Co.........	Pittsburg, Penn.
....	Oliver Iron Mining Co...........	Wolvin Building, Duluth, Minn.
....	Oliver Iron Mining Co...........	Wolvin Building, Duluth, Minn.
9th	Pittsburg & Lake Angeline Iron Co.	Cleveland, Ohio.
....	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
3d	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
3d	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
5th	Volunteer Ore Co................	1400 Alworth Bld., Duluth, Minn.
6th	Mary Charlotte Mining Co.......	Marquette, Mich.
3d	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
....	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
9th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
6th	Niagara Iron Mining Co.........	North Tonawanda, N. Y.
Open pit	Niagara Iron Mining Co.........	North Tonawanda, N. Y.
....	Oliver Iron Mining Co...........	Wolvin Bldg., Duluth, Minn.
....	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
Open pit	Richmond Iron Co..............	1300 Leader-News Bldg., Cleveland, Ohio.
8th	Jones & Laughlin Ore Co.........	3d Ave. & Try St., Pittsburg, Pa.
16th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
5th	Volunteer Ore Co................	1400 Alworth Bldg., Duluth, Minn.
10th	Washington Iron Co.............	Marquette, Mich.
6th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
6th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
2d	American Mining Co.............	Western Reserve Building, Cleveland, Ohio.
5th	Cleveland Cliffs Iron Co..........	Ishpeming, Mich.
14th	National Tube Works Co.........	Frick Bldg., Pittsburg, Pa.
17th	Chapin Mining Co...............	Wolvin Bldg., Duluth, Minn.
....	Penn Iron Mining Co............	1703 Morris Bldg., Philadelphia, Pa.
....	Penn Iron Mining Co............	1703 Morris Bldg., Philadelphia, Pa.
1st	Thomas Furnace Co.............	Milwaukee, Wis.
8th	Loretto Iron Co.................	1400 Fulton St., Chicago, Ill.
3d	Dessau Mining Co...............	Care B. J. Clergue, Montreal, Que.
1st	Munro Iron Mining Co..........	55 Erie Co. Bank Bldg., Buffalo, N. Y.
8th	Pewabic Co.....................	910 Wells Bldg., Milwaukee, Wisconsin.
18th	Penn Iron Mining Co............	1703 Morris Bldg., Philadelphia, Pa.
1st	Antoine Ore Company...........	Republic Building, Youngstown, Ohio.

LIST OF THE ACTIVE IRON MINES OF MICHIGAN.

Name of mine.	Location. County.	Section.	Twp.	Rge.	First shipment.	No. of men employed 1915.	Depth, 1915. Feet.
CRYSTAL FALLS DISTRICT:							
Bristol	Iron	19	43	32	1892	212	1,060
Carpenter	Iron	31	43	32	1914	235	332
Dunn-Richards	Iron	1	42	33	1887	75	1,723
Genesee (with Tobin)	Iron	29,30,31	43	32	1902	......	1,235
Great Western	Iron	21	43	32	1882	25	1,257
Hemlock	Iron	4	44	33	1891	31	1,015
Judson	Iron	13	42	33	1914	76	300
Michigan (with Hemlock)	Iron	9	44	33	1893	......	1,015
Ravenna	Iron	19	43	32	1911	49	350
Tobin	Iron	30	43	32	1901	10	1,235
Warner	Iron	9	44	33	1915	18	543
IRON RIVER DISTRICT:							
Baker-Tully	Iron	31	43	34	1909	267	548
Balkan	Iron	13	42	33	1915	103	232
Baltic	Iron	7	42	34	1901	55	553
Bates	Iron	19	43	34	1915	86	450
Bengal	Iron	36	43	35	1913	63	280
Berkshire	Iron	6	42	34	1908	Idle	365
Caspian	Iron	1	42	35	1903	335	292
Chatham-Riverton	Iron	35	43	35	1907	157	925
Chicagon	Iron	26	43	34	1911	117	712
Cortland	Iron	34	43	35	1912	......	405
Cottrell	Iron	1	42	35	1915	28	265
Davidson No. 1	Iron	23	43	35	1912	60	450
Davidson No. 2	Iron	14	43	35	1912	56	240
Fogarty (see Baltic)	Iron	1	42	35	1907	......	365
Forbes	Iron	14	43	35	1913	107	275
Hiawatha	Iron	35	43	35	1893	98	1,029
Homer	Iron	22,23	43	35	1915	120	258
Osana (James)	Iron	23	43	35	1907	80	428
Dober Isabella (Riverton)	Iron	1,35,36	42,43	35	1898	202	1,000
Rogers	Iron	29	43	34	1914	119	330
Tully (see Baker)	Iron	36	43	35	1910	......	438
Virgil	Iron	24	43	35	1912	......	273
Wauseca	Iron	23	43	35	1910	45	398
Wickwire	Iron	35	43	35	1911	......	313
Youngs	Iron	12	42	35	1905	......	575
Zimmerman	Iron	7	42	34	1908	200	350
GOGEBIC RANGE:							
Anvil and Keweenaw	Gogebic	14	47	46	1887	47	1,663
Asteroid	Gogebic	13	47	46	1906	12	1,130
Ashland	Gogebic	22	47	47	1885	171	1,900
Brotherton	Gogebic	9	47	45	1886	107	1,157
Castile	Gogebic	10	47	45	1906	141	1,770
Colby	Gogebic	16	47	46	1884	429	[illegible]
Davis, Geneva, Royal, Puritan	Gogebic	17,18 19,20	46	47	[illegible]	131	[illegible]
Eureka	Gogebic	13	47	46	[illegible]	221	[illegible]
Ironton (see Colby)	Gogebic	17	47	46	[illegible]	......	[illegible]
Keweenaw (see Anvil)	Gogebic	11	47	46	1914	......	1,663
Mikado	Gogebic	13	47	45	1895	14	[illegible]
Newport and Bonnie	Gogebic	24	47	47	1886	745	2,163
Norrie-Aurora Group	Gogebic	22,23	47	47	[illegible]	1,015	[illegible]
Palms (see Anvil)	Gogebic	14	47	46	[illegible]	[illegible]	[illegible]
Puritan (see Davis)	Gogebic	17	47	[illegible]	[illegible]	......	1,604
Sunday Lake	Gogebic	10	47	45	[illegible]	177	1,391
Tilden	Gogebic	15	47	46	1891	234	1,526
Wakefield	Gogebic	16,17	47	45	[illegible]	370	[illegible]
Yale	Gogebic	16	47	46	1901	40	1,757

1915, WITH LOCATION, OWNERSHIP, ETC.—*Concluded.*

Number or name of level.	Operators.	Address of Home Office.
11th	Bristol Mining Co.	Wade Building, Cleveland, Ohio.
1st	Hollister Mining Co.	1300 Leader-News Bldg., Cleveland, Ohio.
14th	Corrigan, McKinney Co.	Wickliffe, Ohio.
12th	Corrigan, McKinney Co.	Wickliffe, Ohio.
16th	Corrigan, McKinney Co.	Wickliffe, Ohio.
14th	Hemlock River Mining Co.	Cleveland, Ohio, Western Reserve Bldg.
3d	Judson Mining Co.	First National Bank Bldg., Chicago, Illinois.
14th	Hemlock River Mining Co.	Cleveland, Ohio, Western Reserve Bldg.
2d	Hollister Mining Co.	1300 Leader News Bldg., Cleveland, Ohio.
12th	Corrigan, McKinney Co.	Wickliffe, Ohio.
5th	Hemlock River Mining Co.	Cleveland, Ohio, Western Reserve Bldg.
4th	Corrigan, McKinney Co.	Wickliffe, Ohio.
1st	Balkan Mining Co.	Cleveland, Ohio, Western Reserve Bldg.
7th	Verona Mining Co.	Cleveland, Ohio, Western Reserve Bldg.
1st	Bates Iron Co.	New York City, 25 Broad St.
2d	Verona Mining Co.	Cleveland, Ohio, Western Reserve Bldg.
4th	Brule Mining Co.	76 Wade Building, Cleveland, Ohio.
3d	Verona Mining Co.	Cleveland, Ohio, Western Reserve Bldg.
9th	Brule Mining Co.	76 Wade Bldg., Cleveland, Ohio.
7th	Munro Mining Co.	55 Erie Co. Bank Bldg., Buffalo, N. Y.
4th	Wickwire Mining Co.	Buffalo, N. Y.
3d	Oliver Iron Mining Co.	Duluth, Minn., Wolvin Bldg.
1st	Davidson Ore Mining Co.	403 White Bldg., Buffalo, N. Y.
2d	Davidson Ore Mining Co.	403 White Bldg., Buffalo, N. Y.
4th	Verona Mining Co.	Western Reserve Bldg., Cleveland, Ohio.
2d	Jones & Laughlin Ore Co.	3d Ave. & Try St., Pittsburg, Pa.
9th	Munro Mining Co.	55 Erie Co. Bank Bldg., Buffalo, N. Y.
1st	Buffalo Iron Mining Co.	Buffalo, N. Y., Station B.
4th	Mineral Mining Co.	910 Wells Bldg., Milwaukee, Wis.
10th	Oliver Iron Mining Co.	Wolvin Bldg., Duluth, Minn.
1st	Munro Iron Mining Co.	55 Erie Co. Bank Bldg., Buffalo, N. Y.
3d	Corrigan, McKinney Co.	Wickliffe, Ohio.
2d	Wickwire Mining Co.	Buffalo, N. Y.
4th	Mineral Mining Co.	910 Wells Bldg., Milwaukee, Wis.
4th	Wickwire Mining Co.	Buffalo, N. Y.
5th	Huron Iron Co.	Iron River, Mich.
4th	Spring Valley Iron Co.	Wellston, Ohio, Jackson Co.
11th	Newport Mining Co.	First National Bank Bldg., Milwaukee, Wis.
12th	Castile Mining Co.	76 Wade Bldg., Cleveland, Ohio.
25th	Hayes Mining Co.	808 1st National Bank Bldg., San Jose, Cal.
21st	Brotherton Iron Mining Co.	Western Reserve Bldg., Cleveland, Ohio.
17th	Castile Mining Co.	76 Wade Bldg., Cleveland, Ohio.
14th	Corrigan, McKinney Co.	Wickliffe, Ohio.
18th	Oliver Iron Mining Co.	Wolvin Bldg., Duluth, Minn.
19th	Castile Mining Co.	76 Wade Bldg., Cleveland, Ohio.
19th	Corrigan, McKinney Co.	Wickliffe, Ohio.
11th	Newport Mining Co.	First National Bank Bldg., Milwaukee, Wis.
16th	Verona Mining Co.	Western Reserve Bldg., Cleveland, Ohio.
19th	Newport Mining Co.	First National Bank Bldg., Milwaukee, Wis.
22d	Oliver Iron Mining Co.	Wolvin Bldg., Duluth, Minn.
11th	Dunn Iron Mining Co.	First National Bank Bldg., Milwaukee, Wis.
16th	Oliver Iron Mining Co.	Wolvin Bldg., Duluth, Minn.
23d	Sunday Lake Iron Co.	Western Reserve Bldg., Cleveland, Ohio.
23d	Oliver Iron Mining Co.	Wolvin Bldg., Duluth, Minn.
1st	Wakefield Iron Co.	1300 Leader-News Bldg., Cleveland, Ohio.
....	Lake Superior Iron & Chemical Co.	Penobscot Bldg., Detroit, Mich., F. W. Blair, Receiver.

IRON ORE RESERVES

Range.	1911.[1]		1913.[2]	
	Developed. Tons.	Prospective. Tons.	Developed. Tons.	Prospective. Tons.
Gogebic county	18,296,721	13,308,279	23,813,191	7,754,388
Iron county: (Iron River District) (Crystal Falls District)	7,934,687	25,689,155	13,249,683	47,536,233
Menominee: (Dickinson county)	9,082,750	2,567,700	9,682,994	3,100,458
Marquette: (Baraga county) (Marquette county)	36,228,742	56,473,068	34,692,034	51,529,275
State	71,542,900	98,038,202	81,437,902	109,920,354
Total	169,581,102		191,358,256†	

†Of date Jan. 1, 1913 in addition to which there was in stock 4,366,349 tons of ore, making a grand total of 195,724,605 tons.
[1]Estimated by C. K. Leith for Board of State Tax Commissioners.
[2]Estimate by C. K. Leith and R. C. Allen for Board of State Tax Commissioners.

APPRAISED VALUE OF

Range.	Previous appraisals.				
	1911.	1912.	1913.	1914.	1915.
Gogebic	$28,338,100	$27,226,300	$25,849,873	$34,667,028	$34,377,792
Iron county: (Iron River District) (Crystal Falls District)	15,018,475	15,359,664	20,978,709	21,275,945	20,856,919
Menominee: Dickinson county	7,427,500	7,240,625	6,641,925	6,413,003	5,906,443
Marquette: Baraga county	....	*	....	....	....
Marquette county	34,745,000	31,270,500	29,063,714	29,216,139	28,616,453
State	$85,529,075	$81,097,089	$82,534,221	$91,572,115	$89,757,607

*Ten per cent cut from 1911 assessment (approximate figure).

OF MICHIGAN.

1914.[3]		1915.[3]		1916.[3]	
Developed. Tons.	Prospective. Tons.	Developed. Tons.	Prospective. Tons.	Developed. Tons.	Prospective. Tons.
23,765,158	21,113,192	33,764,457	12,838,990	32,181,415	25,743,175
13,337,913	45,045,227	19,258,369	42,961,778	17,332,239	40,935,494
11,062,700	2,129,950	10,134,241	1,701,540	8,035,306	1,671,055
33,095,467	47,919,718	28,629,708	50,235,260	30,655,677	49,239,115
81,261,238	116,208,087	91,786,775	107,737,568	88,204,637	117,588,839
197,469,325*		199,524,343 ‡		205,793,476**	

[3]Estimate by R. C. Allen and O. R. Hamilton for Board of State Tax Commissioners.
*Of date Jan. 1, 1914 in addition to which there was in stock 4,954,830 tons of ore, making a grand total of 202,424,155 tons.
‡Of date Jan. 1, 1915 in addition to which there was in stock 6,596,195 tons of ore, making a grand total of 206,120,538 tons.
**Of date Jan. 1, 1916 in addition to which there was in stock 5,608,465 tons of ore, making a grand total of 211,401,941 tons.

MICHIGAN IRON MINES.[1]

1916 appraisal.		Combined value of mine and ore in stock.	Total tonnage in mine and in stock Jan. 1, 1916.	Assessed value per ton.
Mine.	Ore in stock.			
$28,394,662	$5,915,732	$34,310,394	59,210,760	$0.57946
17,513,288	3,368,387	20,881,675	59,347,807	.35185
3,982,317	1,776,144	5,758,461	10,297,295	.55922
24,220,134	5,570,732	29,790,866	82,546,079	.36090
$74,110,401	$16,630,995	$90,741,396	211,401,941	$0.42923

[1]By Board of State Tax Commissioners.

VALUE OF MICHIGAN IRON ORE SHIPMENTS 1915 FROM REPORT OF APPRAISER OF MINES TO BOARD OF STATE TAX COMMISSIONERS 1915.[1]

Range.	Gross receipts.	*"Beyond the Mine" charges.	Net receipts f. o. b. at the mine.	Shipment. Tons. 1915.	Value per ton f. o. b. mine 1915.	Value per ton f. o. b. mine 1914.
Gogebic—Gogebic county	$14,409,870 95	$4,104,751 83	$10,305,119 12	4,591,040	$2 24461	$2 46
Iron River, Crystal Falls } Iron county	8,559,546 46	2,518,175 86	6,041,370 60	3,261,878	1 85211	1 80
Menominee—Dickinson county	3,694,536 00	1,003,336 47	2,691,199 53	1,302,719	2 06583	1 89
Marquette { Marquette county, Baraga county }	10,081,925 00	2,545,445 89	7,536,479 11	3,995,975	1 88601	2 14
State of Michigan	$36,745,878 41	$10,171,710 05	$26,574,168 36	13,151,612	$2 02060	$2 14

*Includes: 1. Rail freight.
2. Boat freight.
3. Cargo insurance.
4. Lower lake analyses.
5. Selling commissions.

[1]From report of Appraiser of Mines to Board of State Tax Commissioners 1916.

1915 U. S. Production = *55,493,100 gross tons.
Valued at $101,288,984 or average price of $1.83 per ton.

*[1]of which the Lake Superior District produced 46,944,254 tons, or 85 per cent of the total.

Tonnage mined during 1915 is given by U. S. G. S. as 55,526,490 gross tons

of which Minnesota	mined	33,464,660 tons.
Michigan	mined	12,514,516 tons.
Alabama	mined	5,309,354 tons.
Wisconsin	mined	1,095,388 tons.
New York	mined	998,845 tons.
All other states	mined	2,143,727 tons.
Total		55,526,490 tons.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MARQUETTE RANGE, MARQUETTE COUNTY, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Cost of Mining.							
1. General office expenses	a	$0.08148	$0.11454	$0.06125	$0.05057	$0.05898	$0.08927
	b	.07846	.11416	.06121	.04739	.05768	.08603
2. Fire insurance	a	.00075	.00044	.00564	.00397	.00328	.00351
	b	.00037	.00042	.00544	.00378	.00321	.00338
3. Employers liability insurance	a	....	....	.00441	.00339	.00510	.01152
	b	....	....	.00439	.00339	.00509	.01119
4. Taxes	a	.05630	.06870	.08099	.08026	.07564	.15193
	b	.05567	.06863	.07922	.07867	.07471	.14934
5. Depreciation	a	....	....	.09942	.09080	.05299	.09964
	b	....	....	.09942	.09080	.05207	.08920
6. Mining	a	1.33839	1.40609	1.52434	1.50437	1.38899	1.50322
	b	1.32326	1.40609	1.51431	1.50317	1.37501	1.48929
7. Exploration and development	a	.06841	.09228	.09939	.07166	.06095	.08208
	b	.05708	.08664	.09939	.06360	.05389	.07039
8. Construction	a	.08579	.10932	.02212	.06506	.08351	.07106
	b	.06954	.10932	.02212	.05813	.06447	.07061
9. Total cost at mine	a	1.63112	1.79137	1.89756	1.87008	1.72944	2.01223
	b	1.58438	1.78526	1.88550	1.84893	1.68613	1.96943
Beyond the Mine Cost.							
10. Rail freight	a	.26842	.27659	.29435	.29444	.29841	.23228
	b	.26842	.27659	.29425	.29427	.29841	.22936
11. Boat freight	a	.49696	.48986	.44747	.46945	.48127	.35463
	b	.49696	.48986	.44747	.46945	.48127	.35463
12. Cargo insurance	a	.00140	.00192	.00021	.00085	.00088	.00113
	b	.00140	.00192	.00021	.00085	.00088	.00113
13. Analysis at lower lake ports	a	.00047	.00031	.00022	.00069	.00099	.00180
	b	.00047	.00031	.00022	.00069	.00099	.00180
14. Selling commissions	a	.00915	.01198	.01629	.01873	.01852	.02815
	b	.00915	.01198	.01629	.01873	.01852	.02774
15. Total "Beyond the Mine" cost	a	.77640	.78066	.75864	.78419	.80007	.61797
	b	.77640	.78066	.75854	.78402	.80007	.61466

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MARQUETTE RANGE, MARQUETTE COUNTY, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Beyond the mine cost.—*Con.*							
16. Total cost of delivery	a	$2.40752	$2.57203	$2.65620	$2.65427	$2.52951	$2.63020
	b	2,36078	2.56592	2.64404	2.63295	2.48620	2.58409
17. Royalties	a	.12239	.13238	.21741	.18385	.21752	.24763
	b	.12239	.13238	.20704	.17744	.20591	.24036
18. Total cost of delivery to operator	a	2.52991	2.70441	2.87361	2.83812	2.74753	2.87783
	b	2.48317	2.69830	2.85108	2.81039	2.69211	2.82445
Profit and Loss.							
19. Receipts from sale of ore		3.37320	3.77856	3.80000	3.51487	3.70991	3.59091
20. Profit or loss to operator	a	.84329	1.07415	.92369	.67675	.96288	.71308
	b	.89003	1.08027	.94892	.70448	1.01780	.76646
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	.96568	1.20653	1.24052	.95140	1.23339	1.06035
	b	1.01242	1.21265	1.25538	.97272	1.27578	1.09602
22. Assessed valuation per ton by Board of State Tax Commissioners		....	....	....	....	....	.37480

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 inclusive and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MARQUETTE RANGE, MARQUETTE COUNTY, MICH.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Cost of Mining.						
1. General office expenses	a	$0.09194	$0.06932	$0.07754	$0.05827	....
	b	.08885	.06680	.07091	.05686	....
2. Fire insurance	a	.00388	.00357	.00435	.00378	....
	b	.00370	.00341	.00389	.0343	....
3. Employer's liability insurance	a	.01135	.01850	.01869	.02069	....
	b	.01135	.01840	.01824	.02069	....
4. Taxes	a	.14140	.12160	.12630	.13616	....
	b	.13837	.11820	.11917	.13074	....
5. Depreciation	a	.08597	.06817	.14911	.11265	....
	b	.08570	.06803	.13785	.11074	....
6. Mining	a	1.46207	1.45000	1.31975	1.13464	....
	b	1.45260	1.44664	1.30840	1.13367	....
7. Exploration and development	a	.07939	.06080	.07550	.06522	....
	b	.06985	.05170	.03729	.06522	....
8. Construction	a	.07912	.08205	.15827	.05274	....
	b	.06096	.04476	.12717	.05266	....
9. Total cost at mine	a	1.95512	1.87401	1.92951	1.61115	....
	b	1.91138	1.81794	1.82292	1.57401	....
Beyond the Mine Cost.						
10. Rail freight	a	.26284	.30700	.28232	.29318	....
	b	.25878	.30367	.27765	.29318	....
11. Boat freight	a	.29943	.38732	.31371	.32504	....
	b	.29838	.38265	.30677	.32504	....
12. Cargo insurance	a	.00191	.00117	.00091	.00127	....
	b	.00191	.00116	.00091	.00127	....
13. Analysis at lower lake ports	a	.00094	.00465	.00411	.00375	....
	b	.00094	.00463	.00411	.00375	....
14. Selling commissions	a	.01477	.02128	.01749	.01375	....
	b	.01477	.02040	.01597	.01373	....
15. Total "Beyond the Mine" cost	a	.57987	.72142	.61854	.63699	....
	b	.57478	.71251	.60541	.63697	....

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MARQUETTE RANGE, MARQUETTE COUNTY, MICH.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Beyond the Mine Cost.—*Con.*						
16. Total cost of delivery	a	$2.53501	$2.59543	$2.54805	$2.24814	....
	b	2.48616	2.53045	2.42833	2.21098	....
17. Royalties	a	.19117	.19221	.21773	.18120	....
	b	.18478	.18469	.21772	.17913	....
18. Total cost of delivery to operator	a	2.72618	2.78764	2.76578	2.42934	....
	b	2.67094	2.71514	2.64555	2.39011	....
Profit and Loss.						
19. Receipts from sale of ore		2.90551	3.15906	2.82446	2.52302	....
20. Profit or loss to operator	a	.17933	.37142	.05868	.09368	....
	b	.23457	.44302	.17891	.13291	....
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	.45647	.63180	.42552	.38753	....
	b	.50505	.69664	.53398	.42278	....
22. Assessed valuation per ton by Board of State Tax Commissioners		....	.34464	.35034	.34913	$0.36090

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 inclusive and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE GOGEBIC RANGE, GOGEBIC COUNTY, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Cost of Mining.							
1. General office expenses	a	$0.07006	$0.06827	$0.07218	$0.06973	$0.05213	$0.08225
	b	.06908	.06734	.07092	.06901	.05119	.08225
2. Fire insurance	a	.00226	.00256	.00431	.00378	.00415	.00708
	b	.00218	.00245	.00419	.00374	.00413	.00708
3. Employers' liability insurance	a	....	....	.00379	.00495	.00664	.02721
	b	....	....	.00379	.00495	.00664	.02721
4. Taxes	a	.05509	.05834	.06429	.07432	.07565	.19711
	b	.05486	.05809	.06389	.07387	.07522	.19711
5. Depreciation	a	.00648	.00898	.12199	.14554	.12335	.15555
	b	.00648	.00898	.12199	.14554	.12335	.15555
6. Mining	a	1.22206	1.37212	1.46021	1.38712	1.32950	1.43033
	b	1.21186	1.35435	1.45340	1.36994	1.32950	1.43033
7. Exploration and development	a	.08821	.12328	.08133	.12984	.14909	.20058
	b	.08821	.12328	.08133	.09671	.14909	.20058
8. Construction	a	.20230	.22745	.24725	.19922	.08334	.12028
	b	.20230	.22745	.24725	.15107	.08334	.12028
9. Total cost at mine	a	1.64646	1.86100	2.05535	2.01451	1.82385	2.22039
	b	1.63497	1.84194	2.04676	1.91483	1.82246	2.22039
Beyond the Mine Cost.							
10. Rail freight	a	.39625	.39142	.39280	.39047	.39285	.37326
	b	.39625	.39142	.39280	.39047	.39285	.37326
11. Boat freight	a	.73723	.73122	.64708	.63825	.70098	.48302
	b	.73733	.73122	.64708	.63825	.70098	.48302
12. Cargo insurance	a	....	....	....	.00240	.00319	.00290
	b	....	....	....	.00240	.00319	.00290
13. Analysis at lower lake ports	a	....	....	....	.00373	.00210	.00138
	b	....	....	....	.00373	.00210	.00138
14. Selling commissions	a	.03915	.03933	.04572	.05470	.04795	.03548
	b	.03915	.03933	.04572	.05470	.04795	.03548
15. Total "Beyond the Mine" cost	a	1.17263	1.16197	1.08560	1.08955	1.14707	.89604
	b	1.17263	1.16197	1.08560	1.08955	1.14707	.89604

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE GOGEBIC RANGE, GOGEBIC COUNTY, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Beyond the Mine Cost.—*Con.*							
16. Total cost of delivery	a	$2.81909	$3.02297	$3.14095	$3.10406	$2.97092	$3.11643
	b	2.80760	3.00391	3.13236	3.00438	2.96953	3.11643
17. Royalties	a	.36805	.43373	.43762	.45323	.42650	.32388
	b	.36788	.43357	.43741	.43089	.42568	.32277
18. Total cost of delivery to operator	a	3.18714	3.45670	3.57857	3.55729	3.39742	3.44031
	b	3.17548	3.43740	3.56977	3.43527	3.39521	3.43920
Profit and Loss.							
19. Receipts from sale of ore		4.05982	4.73564	3.99683	4.07636	4.69212	3.87255
20. Profit or loss to operator	a	.87268	1.27893	.41826	.51907	1.29470	.43224
	b	.88433	1.29815	.42706	.64109	1.29691	.43335
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	1.24721	1.72164	.97787	1.11784	1.84455	.91167
	b	1.25869	1.74070	.98646	1.21752	1.84594	.91167
22. Assessed valuation per ton by Board of State Tax Commissioners		....	....	....	....	....	.89663

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE GOGEBIC RANGE, GOGEBIC COUNTY, MICH.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Cost of Mining.						
1. General office expenses	a	$0.06157	$0.05763	$0.06841	$0.05757	....
	b	.06157	.05760	.06837	.05757	....
2. Fire insurance	a	.00593	.00526	.00517	.00514	....
	b	.00593	.00526	.00506	.00514	....
3. Employer's liability insurance	a	.01913	.02207	.02667	.01998	....
	b	.01913	.02207	.02632	.01998	....
4. Taxes	a	.13478	.12522	.14182	.16451	....
	b	.13478	.12212	.14122	.16340	....
5. Depreciation	a	.11307	.12644	.09945	.22294	....
	b	.11307	.12594	.09871	.22294	....
6. Mining	a	1.19161	1.37673	1.18169	1.00309	....
	b	1.19161	1.37673	1.17605	1.00294	....
7. Exploration and development	a	.12864	.18028	.23965	.16489	....
	b	.12864	.17977	.23377	.16489	....
8. Construction	a	.04681	.24327	.18114	.13189	....
	b	.04681	.18736	.18082	.13189	....
9. Total cost at mine	a	1.70154	2.13690	1.94400	1.77001	....
	b	1.70154	2.07685	1.93032	1.76875	....
Beyond the Mine Cost.						
10. Rail freight	a	.38032	.44526	.40792	.40970	....
	b	.38032	.4452	.40762	.40970	....
11. Boat freight	a	.46717	.55204	.40087	.43081	....
	b	.46717	.55200	.40054	.43081	....
12. Cargo insurance	a	.00075	.00132	.00097	.00136	....
	b	.00075	.00132	.00097	.00136	....
13. Analysis at lower lake ports	a	.00222	.00248	.00288	.00289	....
	b	.00222	.00248	.00287	.00289	....
14. Selling commissions	a	.04801	.05374	.04889	.04929	....
	b	.04801	.05374	.04883	.04929	....
15. Total "Beyond the Mine" cost	a	.89847	1.05484	.86153	.89405	....
	b	.89847	1.05477	.86083	.89405	....

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE GOGEBIC RANGE, GOGEBIC COUNTY, MICHIGAN.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operator.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Beyond the Mine Cost.—*Con.*						
16. Total cost of delivery	a	$2.60001	$3.19174	$2.80553	$2.66406	
	b	2.60001	3.13162	2.79115	2.66280	
17. Royalties	a	.26506	.30459	.31961	.29208	
	b	.26445	.30275	.31882	.29154	
18. Total cost of delivery to operator	a	2.86507	3.49633	3.12514	2.95614	
	b	2.86446	3.43437	3.10997	2.95434	
Profit and Loss.						
19. Receipts from sale of ore		3.30027	4.11367	3.32900	3.13869	
20. Profit or loss to operator	a	.43520	.61734	.20386	.18255	
	b	.43581	.67930	.21903	.18435	
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	.81333	1.04837	.62292	.69757	
	b	.81333	1,10799	.63656	.69883	
22. Assessed valuation per ton by Board of State Tax Commissioners			.81887	.75715	.71260	$0.57946

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MENOMINEE RANGE, DICKINSON COUNTY, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

			1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
	Cost of Mining.							
1.	General office expenses	a	$0.06131	$0.07640	$0.06687	$0.04570	$0.04250	$0.06026
		b	.06115	.07604	.06655	.04570	.04250	.05975
2.	Fire insurance	a	.00102	.00121	.00768	.00551	.00531	.00701
		b	.00098	.00114	.00758	.00551	.00531	.00701
3.	Employers liability insurance	a	....	....	.00341	.00143	.00605	.00334
		b	....	....	.00341	.00143	.00605	.00333
4.	Taxes	a	.04875	.06366	.11040	.10260	.10141	.15691
		b	.04844	.06331	.10967	.10260	.10141	.15565
5.	Depreciation	a	.00528	.00691	.16494	.14697	.14071	.12837
		b	.00528	.00691	.16123	.14697	.14071	.12818
6.	Mining	a	.98118	1.21721	1.20207	1.21584	1.26711	1.34760
		b	.98118	1.21721	1.20110	1.21584	1.26711	1.34636
7.	Exploration and development	a	.07647	.08296	.13769	.09243	.13863	.16300
		b	.07647	.08296	.13769	.09243	.13863	.16300
8.	Construction	a	.14287	.16885	.19086	.10095	.07037	.05983
		b	.13598	.16885	.19086	.10095	.07037	.05983
9.	Total cost at mine	a	1.31688	1.61720	1.88392	1.71143	1.77209	1.92632
		b	1.30948	1.61642	1.87809	1.71143	1.77209	1.92290
	"Beyond the Mine" Cost.							
10.	Rail freight	a	.32025	.31908	.30214	.32006	.30832	.31708
		b	.32025	.31908	.29914	.32006	.30832	.31544
11.	Boat freight	a	.34010	.33683	.37593	.37786	.39260	.33087
		b	.34010	.33683	.37445	.37786	.39260	.32815
12.	Cargo insurance	a	.00081	.00063	....	.00207	.00205	.00190
		b	.00081	.00063	....	.00207	.00205	.00190
13.	Analysis at lower lake ports	a	....	....	....	....	....	.00010
		b	....	....	....	....	....	.00010
14.	Selling commissions	a	.01403	.01336	.00920	.01645	.02251	.02215
		b	.01403	.01336	.00835	.01645	.02251	.02159
15.	Total "Beyond the Mine" cost	a	.71259	.71345	.70049	.76037	.80337	.68144
		b	.71259	.71345	.69516	.76037	.80337	.67652
	Unclassified		.03740	.04355	.01322	.04393	.07789	.00934

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MENOMINEE RANGE, DICKINSON COUNTY, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Beyond the Mine Cost.—*Con.*							
16. Total cost of delivery	a	$2.02947	$2.33065	$2.58441	$2.47180	$2.57546	$2.60776
	b	2.02207	2.32987	2.57325	2.47180	2.57546	2.59942
17. Royalties	a	.22039	.28258	.23856	.25298	.30194	.24478
	b	.22039	.28258	.23856	.25298	.30194	.24478
18. Total cost of delivery to operator	a	2.24986	2.61323	2.82297	2.72478	2.87740	2.85254
	b	2.24246	2.61245	2.81181	2.72478	2.87740	2.84420
Profit and Loss.							
19. Receipts from sale of ore		3.13222	3.89632	2.93813	3.32263	3.49099	2.79390
20. Profit or loss to operator	a	.88236	1.28309	.11516	.59785	.61359	−.05864
	b	.88975	1.28386	.12632	.59785	.61359	−.05030
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	1.10803	1.57258	.51866	.99780	1.05624	.31551
	b	1.11542	1.57335	.52611	.99780	1.05624	.32266
22. Assessed valuation per ton by Board of State Tax Commissioners		....	....	....	....	....	.63752

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 inclusive and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MENOMINEE RANGE, DICKINSON COUNTY, MICH.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Cost of Mining.						
1. General office expenses	a	$0.06289	$0.04758	$0.06062	$0.06622	....
	b	.06084	.04667	.05911	.06192	....
2. Fire insurance	a	.00749	.00595	.00763	.00714	....
	b	.00684	.00571	.00732	.00682	....
3. Employers liability insurance	a	.01080	.01826	.01805	.01670	....
	b	.01074	.01823	.01801	.01670	....
4. Taxes	a	.18124	.16429	.17651	.17430	....
	b	.17778	.16248	.17534	.16985	....
5. Depreciation	a	.15657	.14460	.12758	.14988	....
	b	.14465	.13500	.12758	.13211	....
6. Mining	a	1.54642	1.42418	1.56567	1.55066	....
	b	1.54135	1.42176	1.56472	1.54777	....
7. Exploration and development	a	.16610	.14462	.15022	.10856	....
	b	.16598	.14462	.14617	.10856	....
8. Construction	a	.07908	.15735	.13618	.06971	....
	b	.07908	.15735	.13618	.06971	....
9. Total cost at mine	a	2.21059	2.10683	2.24246	2.14317	....
	b	2.18726	2.09182	2.23443	2.11344	....
"Beyond the Mine" Cost.						
10. Rail freight	a	.28654	.33679	.31258	.42976	....
	b	.27718	.33176	.31258	.42968	....
11. Boat freight	a	.23712	.29436	.25476	.31703	....
	b	.23061	.28994	.25476	.31703	....
12. Cargo insurance	a	.00038	.00048	.00076	.00068	....
	b	.00036	.00047	.00076	.00068	....
13. Analysis at lower lake ports	a	.00010	.00093	.00110	.00207	....
	b	....	.00089	.00110	.00207	....
14. Selling commissions	a	.01117	.01677	.01165	.02063	....
	b	.00949	.01654	.01158	.02014	....
15. Total "Beyond the Mine" cost	a	.58939	.72872	.61438	.77017	....
	b	.57172	.71899	.61431	.76960	....
Unclassified		.05408	.07939	.03353	....	....

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE MENOMINEE RANGE, DICKINSON COUNTY, MICH.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Beyound the Mine Cost.—*Con.*						
16. Total cost of delivery	a	$2.79998	$2.83555	$2.85684	$2.91334	....
	b	2.75898	2.81081	2.84774	2.88304	....
17. Royalties	a	.19541	.21612	.18070	.19852	....
	b	.19313	.21406	.17810	.18853	....
18. Total cost of delivery to operator	a	2.99539	3.05167	3.03754	3.11186	....
	b	2.95211	3.02487	3.02584	3.07157	....
Profit and Loss.						
19. Receipts from sale of ore		2.61715	3.08203	2.50720	2.83601	....
20. Profit or loss to operator	a	−.37824	.03036	−.53034	−.27585	....
	b	−.33496	.05716	−.51864	−.23556	....
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	−.02626	.39108	−.22206	.07255	....
	b	.00282	.40622	−.21296	.08498	....
22. Assessed valuation per ton by Board of State Tax Commissioners		....	.51957	.46544	.46981	$0.5592

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 inclusive and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE IRON RIVER AND CRYSTAL FALLS DISTRICTS, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Cost of Mining.							
1. General office expenses	a	$0.02142	$0.03991	$0.06483	$0.05912	$0.07662	$0.09376
	b	.01914	.03893	.06270	.05847	.07328	.08936
2. Fire insurance	a	.00502	.00546	.00701	.00367	.00494	.00576
	b	.00499	.00539	.00597	.00334	.00449	.00492
3. Employers liability insurance	a	....	....	.00522	.00551	.00653	.00626
	b	....	....	.00510	.00551	.00618	.00586
4. Taxes	a	.01892	.01942	.03521	.02133	.02625	.09472
	b	.01634	.01937	.03398	.02091	.02502	.08124
5. Depreciation	a	.01089	.01409	.12240	.13189	.11837	.15102
	b	.01089	.01409	.12113	.13123	.11837	.15052
6. Mining	a	1.00419	1.05856	1.25692	.98412	1.17976	1.21722
	b	.93729	1.05850	1.25692	.98017	1.17976	1.20463
7. Exploration and development	a	.26340	.34431	.22709	.10502	.25900	.20459
	b	.14520	.18955	.10211	.07084	.13150	.17734
8. Construction	a	.24753	.30177	.24661	.11833	.17559	.10170
	b	.20844	.25780	.23143	.11135	.14882	.07781
9. Total cost at mine	a	1.57137	1.78346	1.96529	1.42899	1.84706	1.87503
	b	1.34229	1.58363	1.81934	1.38182	1.68742	1.79168
"Beyond the Mine" Cost.							
10. Rail freight	a	.38136	.39229	.37714	.38548	.38549	.36687
	b	.38134	.39229	.37714	.38548	.38549	.35260
11. Boat freight	a	.56819	.57313	.37474	.43736	.47241	.32513
	b	.56814	.57313	.37474	.43736	.47241	.30924
12. Cargo insurance	a	....	....	....	.00079	.00114	.00070
	b	....	....	....	.00079	.00114	.00070
13. Analysis at lower lake ports	a	....	....	....	.00509	.00074	.00058
	b	....	....	....	.00509	.00074	.00058
14. Selling commissions	a	.08732	.08288	.09856	.07241	.07734	.06752
	b	.08732	.08288	.09856	.07241	.07734	.06395
15. Total "Beyond the Mine" cost	a	1.03687	1.04830	.85044	.90113	.93712	.76080
	b	1.03679	1.04830	.85044	.90113	.93712	.72707

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE IRON RIVER AND CRYSTAL FALLS DISTRICTS, MICH.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Beyond the Mine Cost.—*Con.*							
16. Total cost of delivery	a	$2.60824	$2.83176	$2.81573	$2.33012	$2.78418	$2.63583
	b	2.37908	2.63193	2.66978	2.28295	2.62454	2.51875
17. Royalties	a	.20623	.27628	.25170	.23845	.27167	.23104
	b	.19862	.27032	.24005	.23202	.24874	.22370
18. Total cost of delivery to operator	a	2.81447	3.10804	3.06743	2.56857	3.05585	2.86687
	b	2.57770	2.90225	2.90983	2.51497	2.87328	2.74245
Profit and Loss.							
19. Receipts from sale of ore		3.10194	3.95240	3.01281	3.27907	3.66809	2.89477
20. Profit or loss to operator	a	.28747	.84436	−.05462	.71050	.61224	.02790
	b	.52424	1.05015	.10298	.76410	.79481	.15232
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	.50459	1.13473	.31948	1.08084	1.00228	.40996
	b	.73375	1.33456	.46416	1.12735	1.16192	.52654
22. Assessed valuation per ton by Board of State Tax Commissioners		....	....	....	....	....	.44666

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE IRON RIVER AND CRYSTAL FALLS DISTRICTS, MICH.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Cost of Mining.						
1. General office expenses	a	$0.07995	$0.08637	$0.11919	$0.06907	
	b	.07587	.07266	.11035	.06581	
2. Fire insurance	a	.00586	.00733	.00616	.00512	
	b	.00446	.00647	.00533	.00464	
3. Employers liability insurance	a	.01008	.02012	.02950	.01907	
	b	.00962	.01803	.02766	.01887	
4. Taxes	a	.08153	.09690	.13931	.11820	
	b	.06482	.08180	.11462	.10118	
5. Depreciation	a	.11376	.12853	.13560	.09768	
	b	.11157	.12308	.12660	.08973	
6. Mining	a	1.10252	1.18226	1.29722	.93148	
	b	1.07803	1.17207	1.26056	.91655	
7. Exploration and development	a	.26915	.28649	.31585	.16197	
	b	.16993	.14967	.21772	.13915	
8. Construction	a	.19837	.30065	.21799	.08619	
	b	.11781	.18762	.19341	.06803	
9. Total cost at mine	a	1.86122	2.10865	2.26082	1.48878	
	b	1.63211	1.81136	2.05625	1.40396	
"Beyond the Mine" Cost.						
10. Rail freight	a	.37014	.42886	.44558	.43875	
	b	.36538	.41676	.41958	.42991	
11. Boat freight	a	.23496	.27170	.26330	.27286	
	b	.23310	.26135	.24333	.26601	
12. Cargo insurance	a	.00028	.00096	.00097	.00113	
	b	.00028	.00092	.00089	.00110	
13. Analysis at lower lake ports	a	.00046	.00227	.00319	.00302	
	b	.00046	.00204	.00291	.00291	
14. Selling commissions	a	.06269	.05675	.05355	.05622	
	b	.06150	.05415	.04882	.05426	
15. Total "Beyond the Mine" cost	a	.66853	.76054	.76659	.77198	
	b	.66072	.73522	.71553	.75419	

COSTS, PROFITS, LOSSES AND ASSESSMENTS, IRON MINES OF THE IRON RIVER AND CRYSTAL FALLS DISTRICTS, MICH.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports by the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Beyond the Mine Cost.—*Con.*						
16. Total cost of delivery	a	$2.52975	$2.86919	$3.02741	$2.26076	....
	b	2.29283	2.54658	2.77178	2.15815	....
17. Royalties	a	.22019	.28898	.28250	.25014	....
	b	.21170	.22626	.25786	.21777	....
18. Total cost of delivery to operators	a	2.74994	3.15817	3.30991	2.51090	....
	b	2.50453	2.77284	3.02964	2.37592	....
Profit and Loss.						
19. Receipts from sale of ore		2.61385	3.00108	2.63285	2.62411	....
20. Profit or loss to operator	a	−.13609	−.15709	−.67706	.11321	....
	b	.10932	.22824	−.39679	.24819	....
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	.19786	.26042	−.25896	.46103	....
	b	.43259	.57758	−.01233	.55569	....
22. Assessed valuation per ton by Board of State Tax Commissioners		....	.34512	.35776	.32927	$.35185

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, MICHIGAN IRON MINES.

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from the reports of the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
Cost of Mining.							
1. General office expenses	a	$0.06368	$0.08084	$0.06619	$0.05704	$0.05792	$0.08406
	b	.06206	.08021	.06539	.05563	.05652	.08177
2. Fire insurance	a	.00190	.00206	.00579	.00409	.00419	.00545
	b	.00174	.00200	.00550	.00394	.00407	.00517
3. Employer's liability insurance	a	....	....	.00418	.00399	.00599	.01280
	b	....	....	.00415	.00399	.00592	.01258
4. Taxes	a	.04807	.05599	.07330	.06869	.06968	.15022
	b	.04731	.05583	.07222	.06794	.06898	.14592
5. Depreciation	a	.00481	.00636	.12127	.12421	.10092	.12972
	b	.00481	.00636	.12043	.12407	.10060	.12575
6. Mining	a	1.16233	1.29348	1.40644	1.30734	1.31023	1.39408
	b	1.14413	1.28889	1.40057	1.30143	1.30544	1.38582
7. Exploration and development	a	.10683	.14406	.12097	.09864	.13937	.15218
	b	.08433	.11399	.10066	.07897	.11135	.14150
8. Construction	a	.15695	.18758	.15741	.11996	.09994	.08838
	b	.14374	.17959	.15494	.10275	.08804	.08261
9. Total cost at mine	a	1.54457	1.77037	1.95555	1.78396	1.78824	2.01689
	b	1.48812	1.72687	1.92386	1.73872	1.74092	1.98112
"Beyond the Mine" Cost.							
10. Rail freight	a	.33341	.33639	.34304	.34590	.34547	.31765
	b	.33340	.33639	.34244	.34404	.34547	.31266
11. Boat freight	a	.53102	.53428	.48666	.49555	.53537	.37546
	b	.53101	.53428	.48638	.49555	.53537	.37108
12. Cargo insurance	a	.00066	.00080	.00006	.00150	.00182	.00159
	b	.00066	.00080	.00006	.00150	.00182	.00159
13. Analysis at lower lake ports	a	.00015	.00012	.00009	.00239	.00114	.00109
	b	.00015	.00012	.00009	.00239	.00114	.00109
14. Selling commissions	a	.03078	.03221	.03933	.04023	.03920	.03950
	b	.03078	.03221	.03917	.04023	.03920	.03834
15. Total "Beyond the Mine" cost	a	.90564	.91318	.87169	.89295	.93426	.73681
	b	.90564	.91318	.87065	.89109	.93426	.72628
Unclassified		.00964	.00938	.00251	.00738	.01126	.00152

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COSTS, PROFITS, LOSSES AND ASSESSMENTS, MICHIGAN IRON MINES.—*Continued.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

		1906. Per ton.	1907. Per ton.	1908. Per ton.	1909. Per ton.	1910. Per ton.	1911. Per ton.
"Beyond the Mine" Cost.—*Con.*							
16. Total cost of delivery	a	$2.45023	$2.68355	$2.82724	$2.67691	$2.72250	$2.75370
	b	2.39376	2.64005	2.79451	2.62981	2.67518	2.70740
17. Royalties	a	.22560	.26862	.30007	.28448	.30499	.26209
	b	.22434	.26750	.29479	.27457	.29632	.25755
18. Total cost of delivery to operator	a	2.67583	2.95217	3.12731	2.96139	3.02749	3.01579
	b	2.61810	2.90755	3.08930	2.90438	2.97150	2.96495
Profit and Loss.							
19. Receipts from sale of ore		3.44813	4.08242	3.56079	3.59276	3.97701	3.34723
20. Profit or loss to operator	a	.77230	1.13025	.43348	.63137	.94952	.33144
	b	.83003	1.17487	.47149	.68838	1.00551	.38228
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	1.00271	1.40523	.85482	1.04006	1.35543	.72325
	b	1.05918	1.44873	.88671	1.08702	1.40243	.76555
22. Assessed valuation per ton by Board of State Tax Commissioners		....	....	....	....	....	.50435

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 inclusive and item 19 on tons shipped.

COSTS, PROFITS, LOSSES AND ASSESSMENTS, MICHIGAN IRON MINES.—*Continued.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
Cost of Mining.						
1. General office expenses	a	$0.07639	$0.06700	$0.08053	$0.06163	....
	b	.07408	.06275	.07648	.05995	....
2. Fire insurance	a	.00543	.00531	.00541	.00491	....
	b	.00494	.00503	.00502	.00465	....
3. Employer's liability insurance	a	.01325	.01999	.02369	.01964	....
	b	.01312	.01945	.02305	.01959	....
4. Taxes	a	.12900	.12216	.14066	.14311	....
	b	.12330	.11623	.13310	.13784	....
5. Depreciation	a	.10969	.11088	.12570	.15006	....
	b	.10759	.10815	.12009	.14570	....
6. Mining	a	1.30084	1.35877	1.29482	1.07526	....
	b	1.29085	1.35494	1.28172	1.07070	....
7. Exploration and development	a	.15305	.16383	.19263	.12908	....
	b	.12452	.12771	.15829	.12305	....
8. Construction	a	.10014	.19552	.17592	.09034	....
	b	.07357	.13872	.16110	.08551	....
9. Total cost at mine	a	1.88779	2.04346	2.03936	1.67403	....
	b	1.81197	1.93298	1.95886	1.64699	....
"Beyond the Mine" Cost.						
10. Rail freight	a	.32962	.38361	.36805	.38349	....
	b	.32606	.37900	.36085	.38129	....
11. Boat freight	a	.33031	.39878	.32625	.34823	....
	b	.32874	.39425	.31974	.34653	....
12. Cargo insurance	a	.00096	.00107	.00092	.00121	....
	b	.00095	.00106	.00091	.00120	....
13. Analysis at lower lake ports	a	.00114	.00288	.00306	.00310	....
	b	.00112	.00282	.00300	.00308	....
14. Selling commissions	a	.03668	.03930	.03609	.03737	....
	b	.03619	.03837	.03457	.03683	....
15. Total "Beyond the Mine" cost	a	.70524	.83669	.73882	.77340	....
	b	.69959	.82665	.72352	.76893	....
Unclassified		.00653	.01105	.00445	....	....

COSTS, PROFITS, LOSSES AND ASSESSMENTS, MICHIGAN IRON MINES.—*Concluded.*

Compiled by the Appraiser of Mines for the Board of State Tax Commissioners from reports of the operators.

		1912. Per ton.	1913. Per ton.	1914. Per ton.	1915. Per ton.	1916. Per ton.
"Beyond the Mine" Cost.—*Con.*						
16. Total cost of delivery	a	$2.59303	$2.88015	$2.77818	$2.44743	....
	b	2.51156	2.75963	2.68238	2.41592	....
17. Royalties	a	.22255	.25390	.26407	.23872	....
	b	.21800	.23582	.25783	.23136	....
18. Total cost of delivery to operator	a	2.81558	3.13405	3.04225	2.68615	....
	b	2.72956	2.99545	2.94021	2.64728	....
Profit and Loss.						
19. Receipts from sale of ore		2.92708	3.41137	2.92249	2.79402	....
20. Profit or loss to operator	a	.11150	.27732	−.11976	.10787	....
	b	.19750	.41592	−.01772	.14674	....
21. Total profit (operator's profit or loss plus royalty and depreciation)	a	.44374	.64210	.27001	.49665	....
	b	.52309	.75989	.36020	.52380	....
22. Assessed valuation per ton by Board of State Tax Commissioners		....	.43561	.45237	.43546	$.42923

a Total of all operations.
b Total of all operations excluding non-producers.
Note.—All items in 1906 and 1907 figured on basis of tons shipped, tons mined not available.
In all other years items 1 to 9 inclusive figured on tons mined, items 10 to 17 inclusive and item 19 on tons shipped.

PART II. NON-METALLIC MINERALS.

R. A. SMITH.

LIMESTONES OF MICHIGAN.

R. A. SMITH.

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INTRODUCTION.

That Michigan possesses enormous limestone resources has been known for more than a half century yet little was known of the specific or even the general character of many of the beds until recently. A. Winchell,* and C. Rominger,** incidentally have described in various early publications of the Michigan Geological Survey the limestone formations in different localities in connection with the discussion of other geological problems. A. C. Lane† described in detail the limestones of Huron county, W. H. Sherzer†† the limestones of Monroe and Wayne counties, W. H. Sherzer and A. W. Grabau‡ the limestones of the Monroe Formation, A. W. Grabau‡‡ the limestones of the Traverse Formation, and W. M. Gregory§ those of Arenac county. Lane studied in more or less detail the limestone deposits in a number of other localities, and in the Annual Report of the Geological Survey for 1901 published a brief report upon the limestones of the whole state. Brief notes by Lane,§§ Russell,*** and others on limestone were published in some of the other reports. All of the above contributions to the subject, with the exception of the reports on Arenac, Huron, Monroe, and Wayne counties, and on the Monroe formation are out of print and largely out of date.

This report brings together the important facts of the previous reports and adds to these the information afforded by more recent developments, particularly the results of an investigation made by the writer during 1913-14. The economic possibilities of the several limestone formations are presented rather than their geologic relations. The report embraces (1) a discussion of the character origin and classification of limestones, (2) an outline of the geology of the limestone formations of Michigan, (3) their uses, and (4) descriptions of the occurrence, character, development and economic possibilities of the limestone beds of the different counties.

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*First Biennial Rept., Mich. Geol. Survey, 1860.

**Geology of Lower Peninsula, Vol. III, Pt. 1, Mich. Geol. Surv., 1869-1873; and Geology of Lower Peninsula, Vol. III, Pt. 1, 1873-1876.

†Geology of Huron County, vol. VII, p. 11, Mich. Geol. Surv., 1896-1900.

††Geology of Monroe County, vol. VII, p. II, 1896-1900.

‡The Monroe Formation, Pub. 2, Geol. Ser. 1, Mich. Geol. and Biol. Surv. 1909.

‡‡The Stratigraphy of the Traverse Formation, Ann. Report, Mich. Geol. Surv. for 1901.

§Geology of Arenac County, Pub. 11, Geol. Ser. 8, Mich. Geol. and Biol. Surv., 1911.

§§Ann Repts., Mich. Geol. Surv. for 1903, 1905, 1907 and 1908.

***A Geological reconnaissance along the north shore of Lakes Huron and Michigan, Ann. Rept., Mich. Geol. Surv. 1904.

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CHAPTER I.

ORIGIN OF LIMESTONE.

DEFINITION.

According to commercial usage limestone is a rock varying in composition when free from impurities, from pure calcium carbonate to a mixture of 56.35 per cent of calcium carbonate, 45.65 per cent of magnesium carbonate.* In a general sense it is used to denote a rock in which calcium carbonate is the chief ingredient.† In this report, commercial usage has been followed, but the term dolomite is applied to limestones in which the molecular proportions of calcium carbonate to magnesium carbonate approach the ratio of one to one. Descriptive terms are used to distinguish limestones of intermediate composition.

All limestones contain more or less impurities, chemically combined with the lime or magnesia or as separate minerals. The common impurities are iron carbonate, iron oxides and sulphides, silica, alumina, clay, carbonaceous matter, sulphur, and phosphorous. Under the second definition magnesium carbonate is an impurity and generally it is the most abundant.

Calcium carbonate ($CaCO_3$) is usually present as the mineral calcite, magnesium carbonate as dolomite ($CaCO_3$, $MgCO_3$), silica (SiO_2) as sand, chert, quartz, or in combination with clay, ferrous carbonate ($FeCO_3$) as siderite, iron oxides (Fe_2O_3, (Fe_2O_3, $2H_2O$) as hematite and limonite, iron sulphides (FeS_2, FeS) as pyrite or marcasite, alumina (Al_2O_3) as clay or shale. The impurities vary from a mere trace to more than half, when the rock properly is no longer limestone. The color of limestone is largely governed by the impurities. The light blue, buff, yellow, pink, red, and brown tones are due largely to iron oxides and the gray and black to carbonaceous material. Manganese carbonate generally gives a pink or red tinge to limestone.

*According to definition of the National Lime Manufacturers Association. W. E. Emley, Manufacture of Lime, Technologic Papers, U. S. Bur. of Stand., No. 16, 1913, p. 7.
†F. W. Clark, Data of Geochemistry, Bull. 616, U. S. G. S., 1914, p. 548.
†W. G. Miller, Limestones of Ontario, Bur. Mines, 1903, pt. 2, p. 19.
H. A. Buehler, Lime and Cement Resources of Missouri, Vol. VI, 2nd ser., Mo. Geol. Surv. 1907, p. 4.

ORIGINAL SOURCES.

The original source* of limestone is the igneous rocks. Carbon dioxide (CO_2) which is constantly being given off by decaying vegetable and animal matter is readily absorbed by percolating waters and forms a solution of carbonic acid which accelerates the decomposition of the rocks. The carbon dioxide unites with the calcium of the minerals, particularly the lime feldspars and calcium carbonate ($CaCO_3$), the chief constituent of limestone, is formed. Calcium carbonate is slightly soluble in pure water but is much more so in water charged with carbon dioxide. It combines with water forming calcium bi-carbonate ($CaH_2(CO_3)$) which is much more soluble than the normal carbonate.

Upon exposure to the air some of the excess carbon dioxide in the ground water escapes or is removed by various agencies and part of the calcium carbonate is deposited in springs and lakes as travertine, calcareous sinter, marl, tufa, and öolite. All streams, however, carry in solution more or less calcium carbonate and other mineral substances to the sea. Evaporation through the geological ages has tended to concentrate these substances in sea water and owing to the relative insolubility of calcium carbonate, the sea water long ago would have become overcharged with this salt were it not for the fact that various agencies of deposition, chiefly organic, are constantly removing large quantities.

ORGANIC AND INORGANIC DEPOSITS.

Deposits of limestone may be formed through the agency of organisms or directly by precipitation from solutions. The former are termed organic, the latter, chemical deposits. Many of the Michigan limestones are composed of the calcareous remains of animals but others show little or no trace of organic remains. No sharp distinction, however, can be made between limestones of organic and those of purely chemical origin. In the broadest sense all limestones are of chemical origin because the extraction of lime from sea water by living organisms is an organo-chemical process.

Most limestones are formed by accumulation on the sea bottom of the calcareous shells or hard parts of corals, stromatopora, bryozoa, crinoids, and molluscs, which abound in the shallow places of the ocean.

Small or microscopic organisms, chiefly foraminifera, and many other animals and certain plants have also played a smaller though important part in building up calcareous accumulations. Some strata are composed almost wholly of coral, shells, tests of foraminifera, of the hard parts of crinoids or bryozoa, or a mixture of these. The ab-

*F. W. Clarke, Data of Geochemistry, Bull. 616, U. S. G. S., 1916, p. 548.

sence of fossils of lime secreting forms in some limestones is not a proof of inorganic origin. Deformation and thorough recrystallization have obliterated all traces of fossils in most of the pre-Cambrian limestones and in some of later age in areas of extreme metamorphism. The absence of fossils in many limestones is due to the breaking up by the waves, particularly in time of storm, of coral reefs. The detached fragments of the reefs as well as rocks and pebbles on shores, dashed about by the waves, become millstones in grinding up the coral rock, shells, crinoids, etc., into sand and powder or rock flour. The resulting lime-sand and lime-mud are washed and sorted by the waves. The coarser particles are deposited on the slopes of the coral reefs or shores but the finer material may be carried in suspension for long distances before it sinks to the bottom of the ocean as lime-mud. Around modern reefs the water for many miles is milky from this lime-flour, after severe storms. Deposits of lime-sand and lime-mud are now being formed over large areas of sea bottom, especially around coral reefs growing in the open sea. The same process may be observed along the lake shores of Michigan where limestone is exposed to the attacks of the waves. After severe storms the lake waters in the vicinity of Petoskey, Charlevoix, and also of Garden Peninsula are milky white for miles from the rock flour produced through the grinding by boulders and beach shingle along the shore.

Coral reefs with the flanking strata of lime-sand and lime-mud, now compacted and crystallized into hard limestone, are characteristic of several of the limestone formations of Michigan and adjacent states, particularly of the Niagara and the Traverse formations. In the vicinity of Alpena and Petoskey the reefs generally form isolated mounds and more or less continuous and connecting ridges of corals which in places form very complex systems. These coral reefs are more resistant to erosion than associated strata, which explains their elevation above the general level of the rock surface. In some localities they can be traced for considerable distances. Some of them are 100 feet or more wide and 50 to 80 feet high. The lime-sand strata slope away from the reefs at rather steep angles but at relatively short distances the beds become nearly horizontal, and at greater distances gradually give place to the horizontal beds of lime mud.

On the Paleozoic* reefs the grinding tools were largely the colonies of certain corals and stromatopora which were weakly attached and therefore readily broken loose by the waves. In storms these colonies, some of them two or three feet or more in diameter, were rolled about by the waves, grinding the other corals and especially the shells and

*A. W. Grabau. The Devonic Formations of Michigan, unpublished Mss.

crinoids to powder. The frequent occurrence of overturned masses of coral and stromatopora in these reefs and the worn and broken character of all of these fragments near the margins of the reefs testify to the nature of the grinding tools and their work.

Small pelagic organisms, largely foraminifera, flourish on the surface of the ocean, and their tests, sinking to the bottom are forming in clear water seas, deposits of calcareous ooze. Many of the chalk deposits are composed largely of the small or microscopic tests of foraminiferal organisms, similar to those in modern oozes. Various acquatic plants* are locally important in building up deposits of calcium carbonate. The formation of marl is largely due to various species of *Chara*, mosses and algae. These plants extract carbon dioxide from water, and the soluble calcium bicarbonate, being thus robbed of its extra molecule of carbon dioxide becomes the insoluble normal carbonate and is thrown down. The plants growing on marl beds are generally white from the precipitated calcium carbonate. Shelled animals flourish in such waters and their shells locally form a considerable percentage of the marl deposit.

Deposits of travertine are formed in a similar manner around springs by algae and other water loving plants. Some marine limestones may have been formed by plant agencies but definite proof is lacking. When carbonated water enters the sea, calcium carbonate may be precipitated directly. This requires exceptional conditions of temperature and evaporation and the deposition of calcium carbonate in this way is unusual. At present calcareous deposits are being formed in this manner in the everglades of Florida. According to G. H. Drew† bacteria are responsible for much of the marine precipitation of calcium carbonate.

Great masses of tufa are formed in some of the shallow lakes of semi-arid regions where evaporation is rapid and the water is agitated by the winds. Under such conditions the excess carbon dioxide in the water is readily driven off and calcium carbonate is precipitated. The deposition may take place around grains of sand on the lake shores and deposits of öolite sand are thus formed. Evaporation, agitation of the water, and loss of pressure which aid in the escape of carbon dioxide from spring waters are effective agencies in the formation of travertine and sinter around springs, though plants usually play a more or less important role in the process.

*F. W. Clarke, Data of Geochemistry, Bull. 616, U. S. G. S., 1916, p. 550.
†Carnegie Institute, Washington, Pub. 182, 1914.

CHAPTER II.

CLASSIFICATION AND VARIETIES OF LIMESTONES.

As noted on a previous page, on the basis of origin, limestones are classed as organic and inorganic. They may also be divided into two general classes on the bases of (1) texture and (2) composition.* The chief varieties of each class according to texture and composition are given below. Many limestones are mixtures of some of these several varieties.

Varieties based upon Texture.

1. Compact, dense, fine grained, or lithographic limestone.
2. Crystalline limestone (non-metamorphosed).
3. Crystalline limestone or marble (metamorphosed).
4. Oolite and pisolitic limestone.
5. Fossiliferous limestone.
6. Shell limestone (fragmental).
7. Chalky limestone.
8. Conglomeratic limestone (including limestone breccia).
9. Cherty limestone.
10. Fresh water marl.
11. Travertine or calc sinter.
12. Stalactitic and stalagmitic limestone and onyx marble.

Since limestones vary in chemical composition from nearly pure calcium carbonate to a mixture or compound containing theoretically 54.35 calcium carbonate and 45.65 per cent of magnesium carbonate, any classification based strictly upon chemical composition must be largely arbitrary. The combined chemical and physical qualities of limes made from different kinds of stone, however, furnish a good basis for classification. The following are important varieties based upon chemical composition. Other varieties based upon conspicuous impurities such as iron oxides and sulphides, bitumen, and carbonaceous matter may be distinguished but these are of minor importance:

*E. F. Burchard and W. E. Emley, Min. Res. U. S. for 1913, pt. 2, pp. 1515-1520.

Varieties based upon composition.

1. High calcium limestone.
2. Magnesian limestone.
   (a) Low magnesian.
   (b) High magnesian.
3. Dolomite.
4. Argillaceous limestone.
5. Arenaceous and siliceous limestone.

Most of these varieties grade into each other or may show characteristics belonging to two or more varieties.

VARIETIES BASED ON TEXTURE.

Dense fine grained limestone. Many of the limestone strata in Michigan are of very fine grain or of lithographic texture, and apparently represent the lime-mud or rock-flour produced on limestone shores or reefs by the waves. Currents carried the mud in suspension into quiet water where it was slowly deposited. Such limestones, however, may have been the result of direct chemical precipitation in shallow water. The Fiborn limestone is a conspicuous example of the fine grained variety. It has a fine lithographic texture but unfortunately it is very brittle and generally contains numerous small disseminated crystals of calcite rendering it unsuitable for lithographic purposes.

Crystalline limestone (non-metamorphosed). Simple crystallization may in many places more or less obliterate all traces of fossils. Crystallization is brought about through the agencies of pressure, heat, and water. However, some very crystalline limestones, are exceptionally fossiliferous. A very coarsely crystalline but extremely fossiliferous limestone occurs near Bolton, Alpena County, in the Traverse formation. Many of the strata in the "Niagara" formation in Michigan are highly crystalline. The other limestone formations also contain thoroughly crystalline beds.

Metamorphosed crystalline limestone (marble). Commercially the term marble is applied rather loosely to almost any granular crystalline limestone or dolomite, or other rocks susceptible of taking a high polish. Technically, marble is a rock which consists mainly of completely crystalline particles of calcite or dolomite, or of both. Recrystallization results from the metamorphic action of pressure, heat, and liquid and gaseous solutions. Though pressure or heat alone is

sufficient to bring about the complete recrystallization of limestone, generally two or all three agencies appear to have played an important role in the transformation.

Marbles are found in regions which have been subjected to mountain making forces, or igneous intrusions.

Metamorphism usually results in the destruction of fossils, bedding planes, fractures, and other secondary characters of the limestone, and in formation of new minerals from the impurities. Microscopically, marble is composed of crystalline plates of calcite or dolomite, many of which show numerous twinning planes. Granular limestone, so-called marble, on the contrary, usually consists of an aggregation of irregular crystalline plates of calcite in which twinning is absent. This is a marked difference* between marble and crystalline limestone.

Deposits of marble generally occur in lenticular masses interbedded with other metamorphosed rocks, and also as metamorphosed zones along the contact of a limestone with an igneous rock. The Paleozoic strata in Michigan are undisturbed, and contain no marble.

The original limestone beds of the pre-Cambrian rocks of Michigan have been greatly metamorphosed and are now largely marble.

Oolitic limestone. Oolitic limestone is composed wholly or partially of small rounded concretionary grains, resembling fish eggs. Oolites are formed by the deposition of successive concentric coats of calcium carbonate about nuclei, such as grains of sand, in shallow water near shore. Large concretionary grains are called pisolites. The well known Bedford limestone of Indiana is a typical öolitic limestone.

Fossiliferous limestone. Fossiliferous limestone contains noticeable quantities of shells and hard parts of organisms. In some strata certain fossils are present almost to the complete exclusion of others, hence the terms "crinoidal," "coralline," etc.

Shell limestone. Shell limestone is a variety of fossiliferous limestone in which shells, shell fragments, and shell sand form an important part of the rock.

Chalky limestone or chalk. Chalky limestone or chalk is a soft fine grained light colored or white limestone composed chiefly of minute shells of foraminifera. No chalk beds occur in Michigan.

Conglomeratic limestone and limestone breccia. Conglomeratic limestone consists of fragments rounded by wave action held together by

*T. Nelson Dale. The Commercial Marbles of Western Vermont, Bull. 521, U. S. G. S., 1912, p 11.

calcium carbonate cement. Limestone breccia consists of angular fragments similarly cemented. Conglomeratic limestone is comparatively rare but, in Michigan, limestone breccias are characteristic of the Monroe formation.

Cherty limestone. Cherty limestone contains nodules and bands of chert or flint. Chert is a general term applied to impure flint, or jasper. It is composed chiefly of silica (SiO_2). From the fact that chert nodules frequently show the presence of organic remains such as radiolarian tests and sponge spicules it is probable that these in many cases were the nuclei around which precipitation of silica took place.

Marl. Fresh water marl or bog lime is a loose earthy material largely composed of amorphous calcium carbonate. Marl, in a loose sense, also includes deposits of mixed amorphous calcium carbonate, clay, and sand. The term has also been applied to the "green" or glauconitic sands of New Jersey which contain no carbonate. In some fresh water lakes marl is precipitated from the lake waters by plants, mosses and algae. In some deposits shells form a considerable portion of the marl. Many of the lake beds in Michigan contain marl and in some of them marl is being formed at the present time. In the Southern Peninsula alone the total area of known marl beds having an average thickness of ten feet or over, is over 26,000 acres.

Travertine and onyx marble. Travertine or calc sinter, often called calcareous tufa, is a massive porous to compact limestone deposited by water around springs or along streams. It occurs on the faces of limestone bluffs and also in crevices in limestone. Travertine deposited in water much agitated is generally porous and spongy and is called tufa. This form usually contains traces of leaves, twigs, and other organic material upon which it was deposited. Though usually white, the color is often some shade of brown, yellow, green, or red due to various impurities such as iron oxide, manganese, mud, etc. In onyx marble, a more compact variety of travertine, the coloring matters have been deposited in alternating bands producing a beautiful effect. Onyx marble is considered to have been formed generally by precipitation from hot spring waters from deep seated sources. Travertine deposits are generally of small extent and importance.

Stalactitic and stalagmitic limestone. Stalactites are icicle-like forms of calcium carbonate suspended from the roofs of caves. They are deposited from dripping water. Stalagmites are the more or less conical masses of calcium carbonate on the floors of caves. Each

stalagmite has a corresponding stalactite above it, and are similarly formed.

Waters, especially those containing much carbon dioxide in percolating down through fractures or joints in limestone strata, take lime carbonate into solution and in this way tend to widen the openings and form cavities. When lime bearings waters enter such cavities the pressure on the water becomes less and carbon dioxide escapes. More or less evaporation takes place and the operation of both of these factors causes the precipitation of calcium carbonate. Part of it is deposited on the roof of the cavern, forming stalactites. The drip from each stalactite carries some of the precipitated calcium carbonate to the floor and this builds up the stalagmite beneath. The splashing of the drops of water probably drives off more of the carbon dioxide and further precipitation of calcium carbonate takes place on the surface of the stalagmite.

Travertine, stalactitic and stalagmitic limestone are closely related deposits since their formation depends upon the same principles.

VARIETIES BASED ON COMPOSITION.

High calcium limestone. High calcium limestone is distinguished by a low content of magnesium carbonate and relative freedom from other impurities such as silica, alumina, and oxides and sulphides of iron. According to Burchard and Emley* high calcium limestone contains from 93 to more than 99 per cent of calcium carbonate From the viewpoint of the lime manufacturer Peppel† classes limestones containing as low as 85 per cent of calcium carbonate as high calcium. Buehler‡ places the minimum content of calcium carbonate at 90 per cent, which is more nearly in harmony with the general usage and the specifications demanded in Michigan.

Magnesian limestone. From the standpoint of the lime burner, Peppel§ classes all limestone containing from 10 to 30 per cent of magnesium carbonate as magnesian limestone, and limestone containing more than 30 per cent as dolomitic limestone. According to Burchard and Emley§§ limestones carrying magnesian carbonate in any quantity up to 45.65 per cent are classed as magnesian limestones, thus including normal dolomite.

Dolomite. Dolomite is a mineral or rock composed of the double carbonate of calcium and magnesium, Ca Mg $(CO_3)_2$. When pure it

*E. F. Burchard and W. E. Emley, Min. Res. U. S. for 1913, Pt. II, p. 1518.
†S. V. Peppel, Technology of the Lime Industry, Bull. 4, Ohio Geol. Surv. 1906, pp. 252-253.
‡H. A. Buehler, Lime and Cement Resources of Missouri, Vol. VI, 2nd Ser., 1907, p. 17.
§Cit. loc. p. 253.
§§Loc. cit. p. 1519.

contains 54.35 per cent of calcium carbonate and 45.65 per cent of magnesium carbonate. The term "dolomite" is sometimes loosely used by geologists to include limestones containing considerable amounts of magnesium carbonate. In common practice limestones carrying 20 per cent or more of magnesium carbonate are called dolomites. Magnesian limestones are generally mixtures of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) with more or less impurities and the term dolomite should be restricted to the double carbonate which occurs both as a well crystallized mineral and as a massive rock. Owing to impurities it does not generally contain over 44 per cent, and usually somewhat less of magnesium carbonate. In this report limestones containing 40 per cent or over of magnesium carbonate are called dolomites.

The dolomitization of limestones has long been a subject of inquiry and many elaborate experiments have been carried out in order to discover the principles and conditions which might give a plausible explanation of the widespread occurrence of magnesian limestones.

Experimentally dolomite has been formed in a variety of ways but since the conditions under which most of the experiments were conducted cannot reasonably be assumed to have had widespread occurrence in nature, many of the artificial methods of formation are not to be seriously considered in seeking the true explanation. From various experiments and from geological evidence it appears that the formation of dolomite from limestone has been largely through the replacement of calcium carbonate by magnesian carbonate. T. Sterry Hunt* held that dolomite is generally a chemical precipitate. This view is not widely held today. His experiments, however, those of F. Hoppe-Seyler† and others, and the deposition of natural magnesian travertine around warm or hot springs indicate that temperature‡ is an important factor in the formation of dolomite. In general, mixtures of the various chemical substances used in the experiments yielded no dolomite at ordinary temperature but when moderate temperature was employed dolomite was formed.

The character of the original substance‡‡ is apparently another important factor. Aragonite is the less stable form of calcium carbonate and is abundant in coral reefs. Concentrated magnesium sulphate alone or with other solutions even at ordinary temperatures produces mixtures of magnesium and calcium carbonates but not dolomite. If such mixed products are formed in nature the double salt in time would probably be formed through recrystallization.

*Am. Jour. of Sci., 2nd Se., Vol. 28, 1859, pp. 170, 365; Vol. 42, 1866, p. 49.
†Zeitschr. Deutsch. geol. Gesell., Vol. 27, 1875, p. 509.
‡F. W. Clarke, Data of Geochemistry, Bull. 616, U. S. G. S., 1916, p. 561.
‡‡F. W. Clarke, loc. cit., p. 562. C. Klement, Bull. Soc. Belge. geol., Vol. 9, Min. 3, 1895. Min. pet. Mitt. Vol. 14, 1894, p. 526.

The products of organic decomposition—carbon dioxide, ammonium carbonate, and ammonium and hydrogen sulphides, probably play a more or less important part in the process of dolomitization, as shown by Pfaff.* It must be remembered, however, that the tests, shells, and hard parts† of marine organisms contain small, though in some cases relatively large quantities of magnesium carbonates. G. Forchhammer,‡ Gümbel,‡‡ A. G. Högbom‡‡‡, H. W. Nichols,‡‡‡‡ and F. W. Clarke and W. C. Wheeler in investigating the composition of recent shells, corals, and algae found that the content of magnesium carbonate in recent coral, shells, crinoids and the hard parts of sea urchins, starfish, and cuttle stars, ranges from a fraction of one per cent to over 13 per cent. Cold water crinoids, sea urchins, and cuttle stars uniformly contain only small quantities of magnesium carbonate, but in the tropical forms the content is high. Högbom found no such temperature relations in the calcareous algae analyzed by him.

The foregoing data shows that the original sediments must contain very considerable quantities of magnesium carbonate. As a general rule the calcareous deposits as we now find them contain proportionately more of it than the original organic remains. As might be expected the fossil forms show no regularity in composition as do living forms. Leaching§ and the deposition of foreign substances by infiltrating waters have altered the original ratio of lime to magnesia in the organic forms and have brought about a general relative enrichment of the rock in magnesia. Leaching alone either by sea water or surface water is sufficient to bring about the complete dolomitization of a calcareous deposit through the removal of more soluble calcium carbonate, particularly when in the form of aragonite, which is abundant in coral.

Undoubtedly some dolomites have been formed chiefly through leaching but experimental and geologic evidence indicates that replacement of the calcium carbonate by magnesium carbonate is a much more general process than leaching. Geologic evidence in favor of the replacement process is so strong that it has been commonly accepted as the dominant process in dolomitization. A deep boring in the coral deposits of the island of Funafuti indicates dolomitization near the surface, probably through enrichment by leaching, and shows strikingly gradual dolomitization downward from a depth of about 700 feet. The process was nearly complete at 1114 feet. Judd§§ doubtfully ascribes the surface dolomitization to the leaching out of

*F. W. Pfaff, Neus. Yahrb. Beil. Band 9, 1894, p. 485; also Vol. 23, 1907, p. 529.

†F. W. Clarke, Data of Geochemistry, Bull. 616, U. S. G. S., 1916, p. 565.

‡Neus. Yahrb. 1852, p. 854.

‡‡Abhandl. K. Akad. Wiss. Munchen, Vol. II, 1871, p. 26.

‡‡‡Neus. Yahrb. 1894, Band 1, p. 262.

‡‡‡‡Field Columbian Museum, Pub. III, p. 31, 1906.

§F. W. Clarke, Data of Geochemistry, Bull. 616, U. S. G. S., 1916, pp. 566-569.

§§The atoll of Funafuti, published by the Royal Soc., London, 1904. For Judd's report on the chemical examination see pp. 362-389.

the calcium carbonate. In a deep boring at Key West, Florida, there is a gradual enrichment down to about 775 feet but the dolomitization is slight as compared with that at Funafuti. Below this depth, however, the rock is only slightly and irregularly dolomitized. Dolomitization can be accomplished by replacement of calcium by magnesium in spring waters, but this process is unimportant as compared with the action of sea water on coral reefs.

Argillaceous limestone. Limestone containing a considerable amount of clay is termed argillaceous limestone. Clay is chiefly the silicate of alumina. If present in the proper proportions it forms hydraulic limestone. Mortar produced by burning hydraulic limestone will set under water. ''Natural cements'' are made from such limestone, hence the term ''cement rock.''

Arenaceous and siliceous limestone. Arenaceous limestone contains a noticeable amount of sand, usually silica sand of fine grain. Some limestones contain silica in the form of quartz, deposited by infiltrating water in cavities and seams such as geodes, vugs, and veins. The silica may also be deposited as a cement but more often it is concentrated in fossils. In general, arenaceous and siliceous limestones containing 4 per cent or more of silica are of little commercial importance, though sandy limestone of good texture, makes a satisfactory building stone, or if sufficiently hard it may be crushed for road material and concrete.

GRADATIONS* IN LIMESTONES.

From the foregoing descriptions of classes, varieties, and origin of limestone it is obvious that the criteria for distinguishing different varieties are definite, although there are physical and chemical gradations between them. In any formation, uniformity of composition and texture is not generally to be expected.

From these facts the development of a limestone quarry should not be undertaken until the character of the beds have been carefully ascertained both vertically and horizontally. Generally this can be done best by the core drill.

*E. F. Burchard and W. E. Emley. Min. Res. U. S. 1913, Pt. II, p. 1520.

CHAPTER III.

USES OF LIMESTONE.

A generation ago the uses of limestone were few and simple. The chief uses were for lime, flux, building stone, and road making. The progress of industrial chemistry in the last thirty years has developed a large number of new uses. The more important uses* of limestone in its raw and burned condition are as follows:

- Acetate of lime.
- Acetic acid.
- Agricultural limestone.
- Ammonia.
- Ammonium sulphate.
- Basic steel.
- Blast furnace flux.
- Bleaching powder.
- Bone ash.
- Building stone.
- Calcium carbide, calcium cyanimide and calcium nitrate.
- Carbon dioxide.
- Chloride of lime.
- Concrete aggregates.
- Disinfectant and deodorizer.
- Dyeing.
- Fertilizers.
- Finishing lime.
- Gas manufacture.
- Glass making.
- Insecticides.
- Lime burning.
- Lithographing.
- Milk of lime.
- Mortar.
- Oil, fat, glycerine and soap manufacture.
- Paints and varnishes.
- Paper making.
- Portland cement.
- Potassium and sodium dichromates.
- Pottery glazes.
- Refractory bricks.
- Road material and railway ballast.
- Sand-lime brick.
- Soda-ash products, soda, potash and ammonia.
- Sugar manufacture.
- Tanning.
- Wood distillation—wood alcohol, acetate of lime.
- Water softening and purifying.

BUILDING STONE.

Stone satisfactory for building purposes must be homogeneous in texture, relatively hard, free from parting planes, of pleasing color and texture, and resistant to weathering.

*E. F. Burchard and W. E. Emley. Min. Res. U. S. 1913, U. S. G. S., Pt. II, pp. 1592-1593.

ROAD MATERIAL, CONCRETE, AND RAILROAD BALLAST.

Limestone is widely used in the crushed state for road making, for railroad ballast, and as the aggregate material in concrete mixtures. Limestone for such purposes should be hard and resistant to weathering. A high cementing power is desirable in limestone for road material.

LIME.

No other substance can take the place of lime in the building and chemical industries. It is the cheapest and most easily obtainable of the strongly basic oxides, therefore it is the most widely used in manufacturing chemistry.

Definition of Lime.

In a strict chemical sense lime* is the oxide of calcium. It is made by heating limestone ($CaCO_3$) to a temperature sufficient to drive off the carbon dioxide (CO_2). Inasmuch as limestones are composed of varying proportions of calcium and magnesium carbonates with minor amounts of impurities, commercial lime is a mixture of calcium and magnesium oxides.

For practical purposes lime may be defined† as the material obtained from the calcination of a stone in which calcium carbonate is the chief constituent.

Classification of Limes.

Limestone burns to approximately 44 per cent of its original weight, but the impurities, such as sand, clay, and iron lose very little weight in burning, therefore the percentage of these impurities in the lime is nearly double that in the original limestone.

The chemical and physical qualities of limes vary with the amount of magnesia and impurities. Calcium oxide combines energetically with water to form calcium hydroxide or slaked lime. Magnesium oxide in lime burned at the temperatures usually employed in kilns combines very slowly with water. Magnesium oxide burned at temperatures‡ below 1100°C, lower than usually employed in ordinary kilns, combines with water more rapidly than it does when burned at temperatures above 1100°C. In general the higher the content of magnesia in limes, the slower and cooler is the slaking process. The high calcium limes are known to the trade as ''hot,'' ''quick,'' ''fat''

*W. E. Emley. Technologic Paper No. 16, Manufacture of Lime, U. S. Bur. Stand., 1913, p. 14; also Min. Res. U. S. 1913, Pt. II, p. 1556.

†S. V. Peppel. Technology of the Lime Industry. Ohio Geol. Surv., Bulls. 4 and 5, 4th Ser., 1906, p. 249.

‡W. E. Emley. Technologic Paper No. 16, U. S. Bur. Stand., 1913, p. 15.

or "rich" limes and the magnesian as "cool," "mild," or "slow" limes.

If the impurities,—clay, sand, and iron exceed about 5 per cent, they interfere with slaking and generally give a gray or yellow color to the lime.

Many widely different classifications of limes have been made on the basis of differences in composition and in the chemical and physical properties. Some are very simple, others very elaborate. Most of them do not meet the requirements of the trade and only two or three are used in specifications or in technical works. To meet the needs of lime manufacturers, the National Lime Manufacturers' Association adopted the following classification based upon composition:

1. High-calcium lime, 0 to 5 per cent magnesia.
2. Magnesian lime, 5 to 25 per cent magnesia.
3. Dolomitic lime, 25 to 45 per cent magnesia.
4. Super-dolomitic lime, over 45 per cent magnesia.

This classification does not harmonize well with the classification given by Burchard* which conforms closely to the more generally accepted uses of the terms,† viz., high calcium lime, made from limestone containing 93 per cent or more of calcium carbonate; magnesium lime from limestone containing 7 per cent or more of magnesium carbonate; and dolomitic lime, a special grade of magnesian lime, in which the ratio of calcium oxide to magnesium oxide is very nearly 8 to 5. If magnesian limestones are distinguished as "low" and "high" magnesian and the term dolomite is reserved for limestone containing calcium and magnesium carbonates nearly in the ratio of 1 to 1, the limes and the limestones approximately corresponding are as follows:

High calcium lime (0 to 5% MgO) = High calcium limestone (93% or over of $CaCO_3$).

Low magnesian lime (5 to 30% MgO) = Low magnesian limestone (7 to 30% $MgCO_3$).

High magnesian or dolomitic lime (30% or over MgO) = High magnesian limestone (30 to 40% $MgCO_3$) and dolomite (over 40% $MgCO_3$).

Since all classifications are based upon more or less arbitrary distinctions, uniformity of opinion or practice is not to be expected.

Hydraulic limes. The above classifications do not take into account limes containing relatively large amounts of impurities. Limes burned

*E. F. Burchard. Min. Res. U. S. 1913, U. S. G. S., Pt. II, p. 1519.
†W. E. Emley. Min. Res. U. S. 1913, U. S. G. S., Pt. II, p. 1556.

from limestone containing 5 to 10 per cent of sandy and clayey matter,* slake readily without further treatment and harden under water. Limes containing under about 5% of impurities are generally white, but those containing more than about 5 per cent of impurities are usually gray. On the basis of this physical difference Peppel classifies limes as "white" and "gray." This is not a satisfactory classification because any limestone with 3 to 5 per cent of iron will produce a gray or yellow lime.† Limes made from limestone containing from 10 to 30 per cent of sandy and clayey matter and which will not slack until finely ground are called natural or Roman cements. Such limes solidify under water much more quickly than hydraulic limes and are much harder.

USES OF LIME.‡

The main uses of lime are classified as follows:

1. Building lime, for use in plastering and stone work.
2. Finishing lime, for the white coat of plaster.
3. Agricultural lime, for use as a soil amendment or rectifier.
4. Chemical lime, used in various chemical industries.

Building Lime.

Mortar. Lime mortar is composed of mixtures of sand and lime varying usually from three to one, to five to one. Pure lime mortar will not harden under water and should be used only where exposed to the air. Used alone, slaked lime shrinks and cracks on drying, but when mixed with a large volume of sand to form mortar it will not crack and is the most valuable material for wall plaster and brick work. Cement mortars are much stronger than lime mortars but they are rather unsatisfactory substitutes for lime mortar, because they lack plasticity and do not work easily.

The kind of lime best suited for making mortar depends upon the cost of labor, the experience of the workmen available, the volume of mortar which a given lime produces, the ease with which the mortar can be worked, and the strength of the mortar when set. High calcium or "hot" lime sets quickly, magnesian or "cool" lime slowly. The first is unsuitable where much time is required for finishing and the latter in cases where the longer time of setting interferes with building operations. In general high calcium lime is preferred for all rough or

*S. V. Peppel. Technology of the Lime Industry, Bulls. 4 and 5, Ohio Geol. Surv. 1906, p. 253.

†H. A. Buehler. Lime and Cement Resources of Missouri, Vol. VI, 2nd ser., Mo. Bur. Geol. and Mines, p. 17.

‡W. E. Emley. Min. Res. U. S. 1913, U. S. G. S., Pt. II, p. 1581.
S. V. Peppel. Limestones and Lime Industry of Ohio, Bulls. 4 and 5, Ohio Geol. Surv., pp. 254-260.
H. A. Buehler. Lime and Cement Resources of Missouri, Mo. Bur. Geol. and Mines, Vol. VI, 2nd ser., p. 20.

heavy work and high magnesian lime for finishing, though many contractors prefer magnesian lime for the first coat in plastering, because it sets slowly and permits the covering and finishing of large surfaces in one operation. Magnesian lime is generally whiter than high calcium lime, a reason for its preference for final as well as rough coats. Dry hydrate of magnesian lime is much used by the manufacturers of hard wall plasters. Mortar made from hot lime is at first more plastic and easier to work than that from magnesian lime, and is usually preferred for stone and rough brick work. In laying front brick, where much care must be exercised, magnesian lime is generally preferred.

High calcium lime when properly slaked yields a greater amount of putty or paste than magnesian lime, and the paste will carry a greater amount or "load" of sand, therefore the yield of mortar from hot lime is materially greater than from cool lime. The proper slaking of hot limes, however, requires more care and intelligence, and results are often unsatisfactory. The higher the percentage of calcium oxide, the hotter the lime and the greater is the danger of burning in slaking, especially with unskilled labor. Burning decreases the yield of paste, makes it lumpy and decreases its sand holding capacity. Correspondingly the yield of mortar is less and of poorer quality. These two factors are important cost items and form two reasons why hydrated lime is rapidly coming into general use.

It has been found that addition of hot lime to magnesian lime improves the working qualities of the latter and the addition of magnesian lime to hot lime gives a mortar much slower in setting. From this it follows that mixtures of magnesian and high calcium limes would be the most satisfactory for general purposes. For small amounts of mortar this is not practicable but it is commonly done with large amounts of mortar, particularly when mixing machines are used. In such cases the mixtures can be easily varied to produce a mortar suited to the purpose for which it is to be used.

Finishing Lime.

The putty produced when lime is slaked is used directly as a finishing coat on plaster. The putty must work easily under the trowel, must not pop or pit in the wall, and must be nearly white. According to Emley* putty from magnesian limes works better under the trowel and most of them are whiter than high calcium limes. The magnesian limes, therefore, are to be preferred to the high calcium even though the latter give a greater amount of putty. When hot lime is "burned" through

*W. E. Emley. Tests of Commercial Limes, Nat. Lime Mnf. Assoc. Trans., 1913.

improper slaking the lumps contain fine particles of unslaked lime. If used in a finishing coat these particles slowly take up water, expand and fall out, leaving pin holes in the wall. This is called popping* or pitting. On account of the lack of skilled labor for slaking lime it is safer to use commercially prepared hydrated lime.

Agricultural Lime.

Liming of soils. The application of calcium in the form of calcium carbonate, calcium oxide, or calcium hydroxide to soils is termed "liming."

Apparently the Romans two thousand years ago practiced liming† of soils. Long before the value of lime in agriculture was generally known in America the liming of soils was practiced in European countries. Marl has been and still is extensively used in certain parts of Germany in maintaining the productivity of soils. Schultz of Lupitz demonstrated the value of marl as a fertilizer of the sand soils of northern Germany. Ruffin as early as 1818 called attention to the use of lime as a fertilizer and in 1832 published his well known work on "Calcareous manures."

The subject has been and still is being widely investigated by the U. S. Department of Agriculture, the various agricultural colleges and experiment stations. The experimental work has included all forms of lime and almost every variety of soil, soil conditions, and plants. The investigations show that the productivity of most soils is increased by the judicious use of some form of lime. Large areas of lean soils can be made productive with proper application of lime and other fertilizers.

CHEMICAL USES OF LIMESTONE AND LIME.

Soda Ash and Caustic Soda.

Limestone is used for the production of calcium oxide and carbon dioxide in the manufacture of soda ash and related products. The process may be described as follows: Brine is first saturated with ammonia and then carbon dioxide is passed into the resulting solution. Two substances are formed: sodium hydrogen carbonate ($NaHCO_3$) or bicarbonate of soda, and ammonium chloride (NH_4Cl). The bicarbonate of soda is but sparingly soluble and is thrown down. This is common baking soda. When heated in a retort this compound breaks up into sodium carbonate or sal soda, carbon dioxide, and water. Sal soda is used extensively for softening water and in the manufacture

*S. E. Young. On the popping of lime. Amer. Ceramic Soc. Trans., 1913.
†H. J. Wheeler. The Liming of Soils. Farmers' Bull. No. 77, U. S. Dept. Agriculture, 1915.

of glass, and many chemicals. Since ammonia is expensive the mother liquor containing ammonium chloride is treated with lime which replaces ammonia in its compounds and sets free the gas. The ammonia is then distilled off and recovered for further use. Calcium chloride is the end product. When heated under certain temperature conditions it becomes a valuable drying agent because of its great attraction for water.

Magnesium oxide apparently should be as effective in breaking up the compounds of ammonia as calcium oxide but according to Lunge,* magnesian limestone is not suitable for use in soda ash manufacture.

When sodium carbonate is dissolved in water and treated with calcium hydrate, sodium hydroxide or caustic soda and calcium carbonate is formed. The latter being insoluble settles, leaving a clear solution of caustic soda, which is largely used for the manufacture of soap. Magnesia takes no part in the reaction. The impurities form a gelatinous precipitate which does not settle clear, and are therefore undesirable. Quick lime is preferable to hydrated lime since the heat generated in slaking hastens the reaction.

Bleaching Powder.

When moist slaked lime is treated with chlorine, an oxychloride of lime, the bleaching powder of commerce is formed. The bleaching agent is chlorine and since magnesia and impurities in the powder lower the amount of chlorine per unit of weight they are objectionable. Magnesia is especially objectionable because it forms magnesium chloride which absorbs moisture from the air and makes the powder sticky and hard to handle. In this process hydrated lime is preferable to quick lime on account of its greater freedom from impurities and the ease of manipulation.

Soda ash, caustic soda, bleaching powder, and calcium chloride are produced on a large scale in the vicinity of Detroit. The value of these products is more than five-sixths of the total value of the chemical products of the state.

Calcium Carbide.

Calcium carbide (CaC_2), the source of acetylene, is made by fusing a finely ground mixture of lime and coke in an electric furnace. Calcium oxide is the only substance in lime used, therefore all other impurities are objectionable on account of the heat wasted in their fusion. Limestone or hydrated lime could be used but since these must be

*Geo. Lunge, Manufacture of Sulphuric Acid and Alkali. 2nd ed., Vol. III, p. 37, 1891-1896.

reduced to the oxide before fusion and electric power is expensive, lime is preferable.

Calcium Cyanamide and Calcium Nitrate.

The discoveries of the commercial processes for the manufacture of calcium cyanamide and calcium nitrate were made only a few years ago. These substances owe their importance to the fact that they represent two methods of obtaining a commercial supply of nitrogen for plant food from the air. This is of the utmost importance in view of the facts that the commercial supply of combined nitrate will soon be exhausted and that the demand for nitrogen in farm practice and for explosives will then be greater than the means of supply, without resource to these or other new sources.

Calcium cyanamide was first prepared in Europe as a commercial fertilizer. One kind manufactured in Italy was called lime-nitrogen and another kind made in Saxony, Germany, was called nitrogen lime. Calcium cyanamide contains from about 15 to 23 per cent of nitrogen. It is made by heating finely powdered calcium carbide, or lime and coke in an electric furnace at a temperature of about 1100°C and treating the mixture in closed retorts with nitrogen. The product is calcium cyanamide and free carbon, the latter being disseminated throughout the cyanamide and giving it a black color. The nitrogen for the process may be obtained by passing air over heated copper or by the fractional distillation of liquid air.

As in the manufacture of calcium carbide only the calcium oxide is used, hence lime containing the highest percentage of calcium oxide is the most economical. The manufacture and reduction of limestone or hydrated lime to the oxide simply entail unnecessary expense.

Nitric oxide is made by passing air through an electric arc. The nitric oxide (NO) is passed through milk of lime to produce calcium nitrate. This substance, yellowish white in color, is easily soluble in water but deliquesces rapidly in air. This trouble can be avoided if an excess of lime is used in the manufacture or by melting the product, then grinding it fine and packing in sealed containers. The commercial product contains from about 9 to 13 per cent of nitrogen in form a available for plants.

The heat required varies between 2500° and 3000°C. This is much higher than that necessary for calcium cyanamide and the cost is governed directly by the cost of the electricity. With the great possibilities for the production of electricity in this country from water power the manufacture of calcium nitrate may become an industry of the greatest importance.

In this process the actions of the oxides of calcium and magnesium are similar, hence either high calcium or magnesian lime can be used, but, because the continued use of a fertilizer high in magnesia may result in an excess of magnesia in the soil, high calcium or low magnesian lime on the whole is preferable. The impurities are of little importance. Since milk of lime is required, quick lime or hydrated lime is the most economical form for use.

Sugar.

Sugar, like soda-ash products, requires in its manufacture, both calcium oxide and carbon dioxide.

The juice from sugar beets and sugar cane contains various impurities. Some of these discolor the sugar and some change it to glucose. When the juice is heated almost to the boiling point and treated* with an excess of milk of lime, the lime neutralizes the organic acids, breaks up organic compounds, and coagulates the albumen and mucus. In addition it forms an insoluble compound with the sugar, hence carbon dioxide is forced into the liquid to break up this combination. All of the lime is precipitated as calcium carbonate which settles, carrying with it all of the matter in suspension and leaving a clear solution of sugar.

Only calcium oxide is useful in sugar making and the impurities, especially magnesia, are liable to cause mechanical difficulties. Magnesium carbonate, being more soluble in sugar solutions than calcium carbonate, remains in the solution to be deposited later on the tubes in the evaporating pans. Silica forms a gelatinous precipitate which clogs the cloth in the filter presses. Sugar manufacturers usually specify that the content of magnesium carbonate in limestone shall not exceed 2 per cent and the silica 1 per cent.

Michigan is a large producer of beet sugar and demands considerable stone suitable for sugar manufacture. Some quarry companies find it worth while to produce sugar stone by sorting exceptionally high calcium rock from the quarry run. However, the purest calcium stone cannot be economically used for sugar manufacture if it has unsatisfactory burning qualities.

Distillation of Wood.

The primary products† produced from the destructive distillation of wood are wood gas, pyroligneous acid, tars and oils, and charcoal,

*Manufacture of sugar. Internat. Lib. of Technology, sec. 50, p. 36, Internat. Textbook Co., Scranton, Pa., 1902.

†J. R. Withrow. The Chemical Engineering of the Hardwood Distillation Industry. Chem. Engr., Jan. 1916. S. F. Acru, Chem. Engr., Jan. 1916.

W. E. Emley, Manufacture and Use of Lime, Min. Res. U. S., 1913, Pt. II, p. 1590.

of which charcoal is of least commercial importance. Pyroligneous acid is of chief importance to the lime manufacturer because wood or methyl alcohol, acetic, acid and acetone are derived from it. The manufacture of these products requires the use of lime.

Paper.

Wood pulp used for the manufacture of paper is prepared by three different processes,—mechanical, soda, and sulphate. Lime or limestone is used only in the last two. In the soda process,* or alkali process, lime is used to causticise sodium carbonate, thus recovering the caustic soda used in cooking the wood. Calcium oxide is the only useful substance in lime in the soda pulp industry, hence the purest high calcium lime is most desirable. The magnesia and impurities are merely inert substances. Lump lime is preferred to hydrated lime on account of the heat generated in slacking which hastens the chemical reaction with the soda.

In the sulphite or acid process, ''bisulphite liquor'' is used for dissolving the cementing substances of wood. The liquor may be prepared by subjecting limestone to the solvent action of sulphur dioxide and water or milk of lime may be treated by sulphur dioxide. Since magnesium sulphite is much more soluble than calcium sulphite, a much stronger liquor, fundamental to the economic success of the process, can be prepared. In addition a high magnesian liquor gives a better color to the pulp, makes it softer, and this results in better felting qualities when it is made into paper. Impurities are not injurious.

Sand-Lime Brick.

Sand-lime brick are manufactured from a mixture of fine grained sand and hydrated high calcium lime. The brick are pressed into form and then subjected to high pressure steam. The lime combines with a part of the sand, forming a calcium silicate which acts as a cement to bind the sand grains together. Complete hydration of the lime is necessary or the subsequent hydration and expansion will cause the brick to swell or crack. For most purposes the complete hydration of lime is not necessary, hence most of the commercial hydrated lime contains small amounts of unslaked lime. For this reason sand-lime brick manufacturers buy quick-lime and do their own hydrating or have it hydrated according to certain specifications.

Magnesian lime is not well adapted for use in this industry because of the difficulty of completely hydrating† the magnesia and also be-

*W. E. Emley, Min. Res. U. S., 1913, Pt. II, p. 1590.
†S. V. Peppel, Sand-Lime Brick, Bull. 5, p. 38, Ohio Geol. Surv., 1906.

cause the magnesia reduces the strength of the resulting product. The impurities, especially silica or clay owing to their fluxing qualities, are beneficial if they are not present in excessive amounts.

Glass Making.

The essential raw materials* of the common varieties of glass are lime, sand (silica), soda ash (sodium carbonate), and salt cake (sodium sulphate). Red lead (lead oxide) may be used instead of lime and potassium carbonate may replace soda ash. Small amounts of other substances such as carbon, arsenic, etc., are also used to secure certain physical and optical properties. Sand composes from 52 to 65 per cent of the mixture of raw materials. In mixtures for plate glass, limestone equals by weight about one-fourth of the sand, for window glass about two-fifths, and for green bottle glass about one-third. Calcium oxide† is a necessary constituent of these varieties of glass and also of much of the pressed and blown glass. It acts as a flux. Magnesia, on the contrary, makes the mixture of raw materials more difficult to melt, thus more heat is consumed than would otherwise be necessary. It is used, however, when certain optical properties are desired.

For bottle and window glass‡ ground limestone is used but for plate and flint glass ground lime is much more preferable. When ground limestone is used the bubbling or foaming of the viscous half fused mixture, due to the evolution of the carbon dioxide, necessitates the use of much larger glass pots, which are very expensive. The manufacturer of window and bottle glass uses large tank furnaces in which the evolution of gases gives rise to no physical difficulties.

For the manufacture of common bottle and window glass the impurities commonly present in limestone are of little importance, but for white glass the iron oxide in the stone should be less than 0.3 per cent. When present in amounts much above one-half per cent it detracts markedly from the brilliancy, clearness, and transparency of the finished product.

Water Softening.

In many parts of the state, particularly in limestone regions, well waters are very hard, being unfit for boiler or laundry purposes. In many cases most of the hardness is only "temporary." This "temporary hardness" is due to calcium carbonate which, though only

*E. B. Mathews and J. S. Grasty. The limestones of Maryland, p. 234, Md. Geol. Surv., 1910.
W. G. Miller, The limestones of Ontario, XIIIth Rept. Bur. Mines, 1904, Pt. II, p. 5.
E. F. Burchard, The requirements of sand and limestone for glass making, Bull. 285n, p. 452, U. S. G. S., 1906.
†W. E. Emley. Manufacture and use of lime. Min. Res. U. S., 1913, Pt. II, p. 1586, U. S. G. S.
‡S. V. Peppel, Bull. 4, Limestones and lime industry of Ohio, p. 242, Ohio Geol. Surv., 1906.

slightly soluble in pure water, is held in solution by carbon dioxide in the form of calcium bicarbonate. When the carbon dioxide is removed, this becomes insoluble calcium carbonate, which is precipitated. Carbon dioxide may be driven out by boiling but neutralization with lime is more practicable and cheaper. Lime combines with the carbon dioxide to form calcium carbonate which, together with the original calcium carbonate in the water, is precipitated. Since magnesium oxide and impurities are inert substances, the purest high calcium lime is preferred. The lime is usually carefully slaked* to a cream and fed into the main body of the water in an automatically regulated stream. From the fact that well burned high calcium lime produces not only the greatest quantity but also the best quality of cream, it is the most satisfactory and economical.

Gas Purification.

Gas manufactured by the distillation of coal contains a number of objectionable substances such as carbon dioxide and hydrogen sulphide. These may be removed by passing the gas through layers of moist slaked lime. Calcium oxide is the only useful constituent† in lime but magnesium oxide and the impurities are not injurious.‡ For this reason the purest high calcium lime is the most economical. Hydrated lime is the most convenient form because it is already prepared and easier to handle.

By-Products of Coal Distillation.

The chief supply of ammonia is obtained from crude coal gas. The ammonia is removed by washing the crude gas before it reaches the lime purifiers. The resulting solution contains free and combined ammonia. The free gas is distilled off and collected. The addition of lime breaks up the ammonia compounds thus liberating free ammonia, which similarly can be recovered by distillation. According to Peppel§ both high calcium or magnesian lime may be used but Lunge asserts that magnesian lime is not suitable for this purpose. Hydrated and quick lime appear to give equally satisfactory results.

Paints.

Ground lime, air slaked lime, levigated chalk (natural whiting) and chemically precipitated calcium carbonate are extensively used in

*W. E. Emley, Manufacture and use of lime. Min. Res. U. S. 1913, Pt. II, p. 1587.
S. V. Peppel, Uses of limestone in Ohio. Bull. 4, p. 244, Ohio Geol. Surv. 1906.
†W. E. Emley, Manufacture and use of lime. Min. Res. U. S. 1913, Pt. II, p. 1588.
‡Chas. Hunt, Gas Lighting, p. 136, 1900.
§S. V. Peppel. Manufacture and Use of Lime. Bull. 4, p. 244, Ohio Geol. Surv., 1906.

paint and pigment industries. One of the most essential qualities is fineness of grain, though color or chemical composition may be equally important. Because limestone is rarely white and is difficult to grind sufficiently fine to meet the requirements of the paint manufacturer, air slaked lime and hydrated lime are the more preferable materials.

Cold water paints* consist essentially of mixed hydrated lime and casein. Obviously, quick lime cannot be used with such substances. Magnesian hydrate is probably preferable to high calcium hydrate on account of its superior spreading qualities.

Glycerine, Lubricants, and Soaps.

Soap and glycerine manufacturers use considerable quantities of lime. Most common fats are compounds of glycerine with various organic acids. When fats are heated with lime and water under pressure lime replaces the glycerine in the compounds, thus liberating the glycerine. Most of the glycerine produced in the United States is made from fats and oils extracted from garbage. When the "lime soaps" formed in this process are mixed with heavy petroleum oils they make valuable lubricants or greases, especially for heavy machinery and for use at high temperatures. Much of the "lime soap," however, is treated with sulphuric acid to liberate the fatty acids for use in the manufacture of soap and related products. For the manufacture of these products lime is again needed to convert sodium or potassium carbonate into the caustic or hydroxide form. For these purposes calcium oxide is the only useful constituent in the lime, therefore pure high calcium lime gives the most satisfactory results. Magnesia and the impurities, however, are not injurious. Either slaked lime or quicklime can be used, though quicklime may be preferable because the additional heat of slaking tends to hasten the reactions.

Tanning.

In the process of tanning leather† lime softens and loosens the hair and adhering particles of fat and flesh so that they can be readily removed by scraping. It also causes an expansion of the pores, called "plumping," which permits of a larger absorption of oil and tallow. This gives greater weight and solidity to the leather. High calcium limes are desired for most tanning operations, though for some varieties of leather such as morocco the presence of magnesia is desirable. Magnesia and clay are injurious‡ because they not only diminish the amount

*W. E. Emley, Manufacture and Use of Lime, Min. Res. U. S. 1913, Pt. II, p. 1591.
†S. V. Peppel. The Uses of Limestone in Ohio. Bull. 4, p. 245, Ohio Geol. Surv. 1906.
‡H. R. Proctor. Principles of Leather Manufacture, p. 121, Spon & Chamberlain, New York, 1903.

of calcium oxide but make the lime more difficult to slake. Iron oxides, becoming mechanically fixed in the grain of the leather, may cause stains. The trouble incident to the slaking of magnesian lime may be avoided through the use of hydrated lime. Since hydrated lime needs no preparation and is easier to handle it is the more preferable form.

Insecticides.

Lime is an important ingredient in many insecticides. Calcium oxide is the only useful constituent, though magnesia and the impurities are not injurious. The material is usually applied in liquid form by some form of atomizer. Either slaked or hydrated lime can be used with water or other liquid. It is very difficult to slake lump lime to a cream free from coarse particles. These are apt to clog the spraying apparatus, therefore hydrated lime screened to the desired fineness should be much more satisfactory.

Furnace Linings.

Pure lime is a most refractory substance.* It fuses only at the high temperatures of the electric furnace.

Theoretically high calcium lime should be a satisfactory material† for lining open hearth furnaces, but the rapidity with which it slakes upon exposure to air makes this substance valueless for this purpose. Upon reheating, the driving off of the moisture reduces the lime to powder, therefore it has little durability. Calcined dolomite ($CaCO_3$, $MgCO_3$) slakes very slowly upon exposure to air and is much less liable to crack with changes of temperature but calcined magnesite ($MgCO_3$) is far superior to the purest dolomite in these respects and is now always used for the original bottoms in openhearth furnaces. Its high first cost, however, has until recently prevented its general use. As a consequence dolomite, on account of its cheapness, has been commonly used for the working linings and the repairing of basic furnaces and in some cases for the whole lining. It is impossible to set a dolomite bottom as dense and vitreous as magnesite, hence portions of the bottom from time to time will break loose and float even with the most watchful care.

The permanent lining of the furnace is usually built of basic brick, generally magnesite brick, chromite, etc. A working lining of crushed basic material, dolomite or a mixture of dolomite and magnesite with a binding material such as tar or molasses to hold it in place, is then

*E. B. Mathews and J. S. Grasty. The Limestones of Maryland, Vol. VIII, Pt. III, p. 234 Md. Geol. Surv. 1910.

†Harbison-Walker Refractories Co. A Study of the Open Hearth, p. 22, Pittsburg, 1912.

tamped upon the permanent lining to the depth of two or three feet. Formerly it was thought necessary to use lime but at present crushed limestone is found to give just as satisfactory results since the stone is calcined to lime during the operation of the furnace.

The stone must be low in silica and alumina because these materials fuse readily with lime, thus tending to destroy the lining. A stone suitable for openhearth lining should contain less than 1 per cent of silica and 1.5 per cent of alumina and iron, and not less than 35 per cent of magnesium carbonate, though in practice stone considerably short of these specifications is often used.

Blast Furnace Flux.

Iron ores generally carry considerable impurities or gangue material such as silica, alumina, etc. The gangue material is generally acid* in nature and not readily fusible. To remove this relatively infusible material its composition must be so changed that fusibility will be increased. This may be brought about by supplying a suitable base to unite with the acid material. Limestone furnishes the cheapest and most active of the bases, namely calcium oxide, hence its universal use as a flux in the smelting of iron ores or other metallic ores containing acid gangue material.

The quantity of limestone necessary for smelting iron ore depends upon the amount of acid material present to be neutralized,—in general, the greater the acid impurities the greater the amount of base required. In some iron ores the gangue includes a considerable percentage of basic material which will neutralize an equivalent amount of the acid material. In such cases only enough limestone is added to flux the excess acid material in the ore and in the ash of the fuel. In 1914 approximately 15,300,000 tons of limestone were used in smelting approximately 40,600,000 tons of iron ore or about three-eighths tons of limestone to one ton of ore.

It follows that the value of a limestone for fluxing purposes depends upon the amount of available bases present. This consists of that portion of the stone remaining after the carbon dioxide, the silica, alumina, and other acid impurities, and the portion of the base required to flux the acid impurities have been deducted.

High calcium limestone is generally preferred for blast furnace work yet practical tests indicate that dolomite or magnesian limestone can be used for flux in part or whole with satisfactory results.† Small quantities of magnesia do not appreciably affect the behavior of the

*R. Forsythe. The Blast Furnace and the Manufacture of Pig Iron, p. 86, D. Williams & Co., New York, 1913.

†R. Forsyth. The Blast Furnace and the Manufacture of Pig Iron, p. 88, D. Williams Co., New York, 1913.

flux but when present with calcium in considerable amount it makes the slag more fusible. According to Mathews and Grasty* magnesia has less affinity for sulphur and phosphorus than calcium oxide, hence its presence is undesirable.

In openhearth work,† however, high calcium, low silica-alumina limestone is demanded. The specifications usually required are that the silica must be under 1 per cent, the alumina under 1.50, and the magnesia under 5 per cent.

Hydraulic Limes and Cements.

Hydraulic limes. Lime burned from limestone, either high calcium or magnesian, containing 5 to 10 per cent‡ of sand and clayey material are termed hydraulic lime. Hydraulic limes will slake as they come from the kilns without further treatment. If the sandy and clayey material in the limestone exceeds about 10 per cent, the resulting lime fails to slake without first being finely ground and is a hydraulic cement.

No hydraulic limes are produced in Michigan, though many strata in the Traverse formation and the Trenton limestone apparently have the desired composition.

Hydraulic Cements. There are three principal classes§ of hydraulic cements, viz., (1) Portland cement, (2) natural, or Roman, and (3) Puzzolan.

Natural Cements. Natural cement is made by grinding finely the calcined product from burning at a temperature below 1000-1100°C to incipient vitrification an argillaceous limestone containing over 10 per cent of siliceous and argillaceous matter. The limestones from which the commercial natural cements in the United States are made contain from 13 to 35 per cent§§ of clayey material of which 10 to 22 per cent is silica. Natural cement is usually yellow or brown. It sets more rapidly than Portland cement and has lower specific gravity and tensile strength.

Portland Cement. Portland cement is made by finely pulverizing the clinker produced by burning to incipient fusion an intimate mixture§§§ of finely pulverized and properly proportioned argillaceous and calcareous materials with the addition of such other substances, not to

*Mathews and Grasty, loc. cit.

†E. B. Mathews and J. S. Grasty. The Limestones of Maryland, Vol. VIII, Pt. III, p. 249, Md. Geol. Surv., 1910.

‡S. V. Peppel. The Uses of Limestone in Ohio, Bull. 4, p. 252, Ohio Geol. Surv. 1906.

§H. A. Buehler. The Lime and Cement Resources of Missouri, Vol. VI, 2nd ser., p. 18, Mo. Bur. Geol. & Mines, 1907.

§§E. C. Eckel. Cement, Limes and Plasters, Chapter XVII.

§§§E. F. Burchard. Cement, Min. Res. U. S. 1914, Pt. II, p. 222, U. S. G. S.

exceed 3 per cent, as may be necessary to control certain properties. The proportions of the mixture are approximately three parts of calcium carbonate to one part of silica, alumina, and iron oxide. Portland cement is made from carefully proportioned mixtures and is burned at a temperature (approaching 3000°F) sufficient to fuse or clinker.

The raw calcareous ingredients are limestone, marl, and chalk, and the argillaceous and siliceous ingredients, clay, shale, and slate. Blast furnace slag, which is mainly fused lime, alumina, and silica, contains all of the ingredients of Portland cement, though not in the prescribed proportions.

Formerly 4 per cent of magnesia was considered the maximum permissible in Portland cement. To secure such a product only pure high calcium limestone may be used. Incomplete results of an important investigation carried on by the U. S. Bureau of Standards* indicate that satisfactory cement can be made with a magnesia content in the finished cement of about 7.5 per cent. If more thorough tests substantiate the preliminary tests the range of raw materials will be greatly extended and many quarries containing beds relatively high in magnesia may be operated without sorting necessary under the present specifications for raw materials.

Puzzolan Cement. Puzzolan cement is a finely ground mechanical mixture of siliceous and aluminous materials such as blast furnace slag or volcanic ash, and slaked lime. Slag cement is made extensively at a number of the larger blast furnaces in the United States. The hot slag is granulated in cold water, dried, and then ground with slaked lime. Puzzolan cements are generally light bluish in color and of lower specific gravity and less tensile strength† than Portland cement, and are considered better adapted for use under water than in air.

Miscellaneous Uses of Limestone and Lime.

Limestone and lime are used for many other purposes,‡ among which may be mentioned the manufacture of dichromates, magnesia, bone ash, glue, and varnish; as the refining and purifying agent in the distillation of mercury; in the clarification of grain, in refining fats, greases, butter, linseed oil, and petroleum; in preserving eggs, and as a general disinfectant and deodorizing agent; as a filter in the paper,

*P. H. Bates. Progress Report. The properties of Portland cement having a high magnesia content: Concrete-Cement Age, Cement Mill section, Mar. 1914, pp. 29-33, 38. See also extract, E. F. Burchard, Min. Res. U. S. 1914, Pt. II, pp. 245, 246, U. S. G. S.

†E. C. Eckel. Portland cement materials and industry of the United States, U. S. Geol. Surv. Bull. 22, p. 18, 1913.

‡E. F. Burchard, Production of Lime in 1911, Min. Res. of U. S. for 1911, U. S. Geol. Surv., Pt. II, pp. 645-718.

See also W. E. Emley, Manufacture and Use of Limestone, Min. Res. U. S. for 1913, U. S. G. S., p. 1592.

textile, linoleum, and rubber industries; as a mordant in dyeing; as an abrasive in polishing; in the manufacture of calcium light pencils, and of magnesium for flash-light powders; as lime water in medicine; for the recovery of potassium cyanide used in extracting gold and silver from ores; to neutralize the sulphuric acid used in pickling steel, and for a great variety of minor purposes.

CHAPTER IV.

GEOLOGY OF LIMESTONE FORMATIONS.

GEOLOGIC DISTRIBUTION.

Limestone occurs in rocks of all ages from the Archean to the Recent. In Michigan it occurs in Algonkian and Paleozoic rocks. Marl or bog lime occurs in the inland lakes.

ALGONKIAN LIMESTONES.

Algonkian limestones occur only in the Lower Huronian group of the iron bearing districts of the Northern Peninsula. In the Marquette iron bearing district the limestone formation is called Kona dolomite; in the Crystal Falls, Menominee, Sturgeon River, and Felch Mountain districts, the Randville dolomite; in the Iron River district, the Saunders formation; and in the Gogebic district, the Bad River limestone. They are heavily magnesian, generally approaching normal dolomite in composition. Locally there are thick pure beds but generally these formations contain interbedded slate or quartzite, and in most places abundant cherty and argillaceous impurities and silicate minerals. These impurities occur in bands parallel to the bedding,

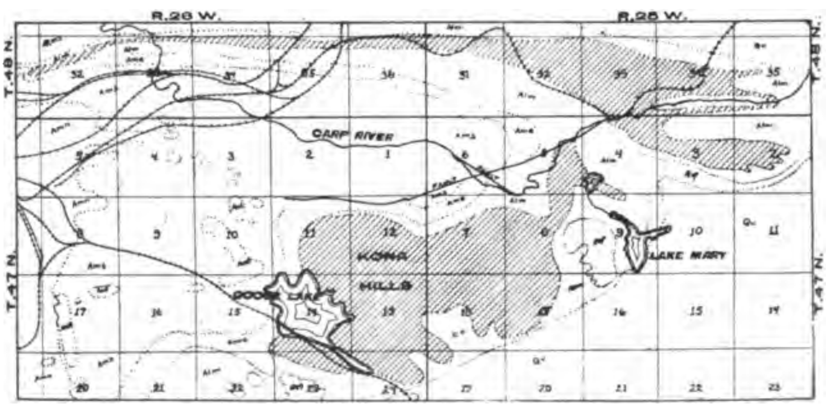

Figure 1. Map showing distribution of Kona dolomite. (After Van Hise, Bayley and Smyth, Monograph 28, U. S. Geological Survey).

in irregular seams and masses, and intimately intermingled with the dolomite. In some places the color is white, in others it varies from white to pink, red, buff and brown, and even light and deep blue. The generally siliceous character (see analyses) of the Lower Huronian dolomites makes them unsuitable for most purposes, except for crushed stone, hence they are of little economic importance.

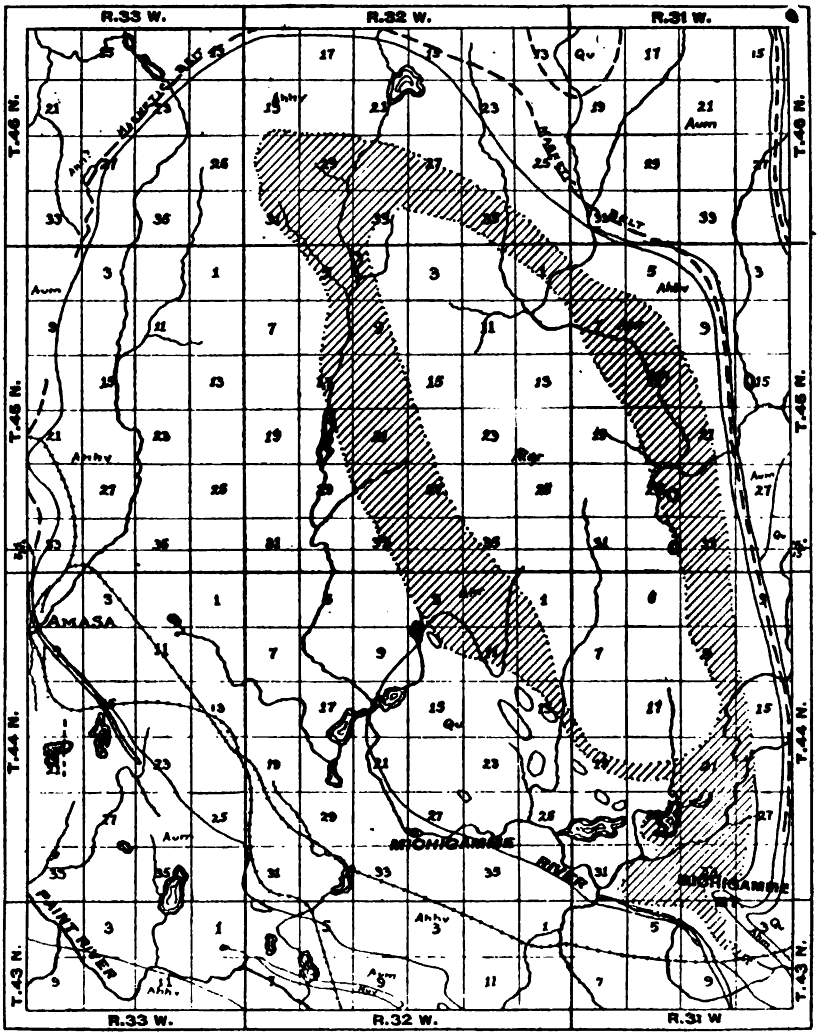

Figure 2. Map showing distribution of Randville dolomite northeast of Crystal Falls. (After Clements and Smyth, Monograph 36, U. S. Geological Survey).

Kona dolomite. The Kona* dolomite (fig. 1) forms a westward facing-U in the eastern part of the Marquette iron district, the arms of which terminate near Teal Lake on the north and Goose Lake on the south. The exposures are usually in the form of sharp and abrupt cliffs cut by ravines or separated by drift filled valleys. The Kona formation is dominantly dolomite with interstratified layers of shale,

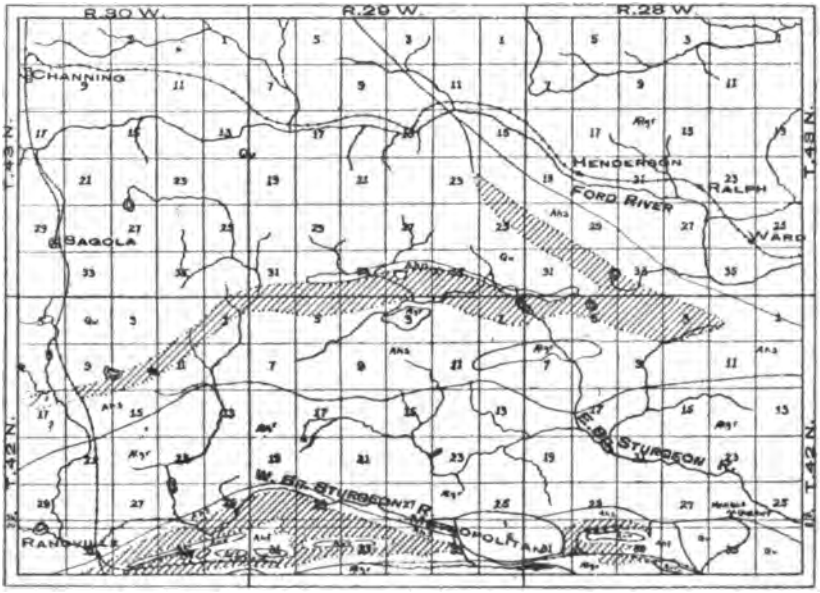

Figure 3. Map showing distribution of Randville dolomite in the Felch Mountain and Sturgeon River district. (After Smyth and Clements, Monograph 36, U. S. Geological Survey).

graywacke and quartzite. The dolomite beds are from a few inches to many feet thick, but even the purest beds contain thin cherty layers and clastic material. The color varies from pink and red to dark brown. The total thickness of the Kona formation ranges from about 200 or 250 feet to apparently 600 or 700 feet.

Owing to folding and consequent metamorphism the dolomite is finely shattered and the siliceous and argillaceous impurities are altered to quartzite, schist, and slate. Locally the graywacke, quartz, and cherty quartz layers are brecciated. The Kona formation grades upward into the Wewe slate and downward into the Mesnard quartzite.

Randville dolomite. The Randville dolomite† occurs in the Crystal Falls, Menominee, Felch Mountain, Calumet and Sturgeon River districts.

*C. R. VanHise and C. K. Leith. The Geology of the Lake Superior District, Mon. LII, U. S. Geol. Surv. 1911, p. 258.

†C. R. VanHise and C. K. Leith. Geology of the Lake Superior District, Mon. LII, U. S. Geol. Surv. 1911, pp. 293, 300, 302, 333.

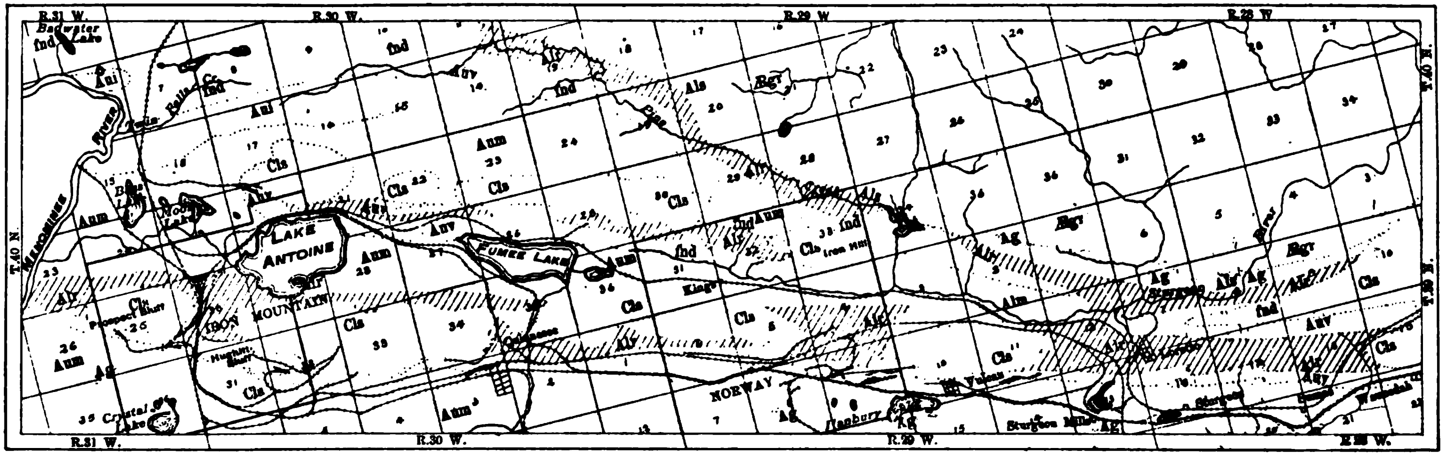

Figure 4. Map of the Randville dolomite in the Menominee district. (After W. S. Bayley, Monograph 46, U.S. Geological Survey).

In the Crystal Falls district (fig. 2) it has a maximum thickness of about 1500 feet. It varies from coarselycrystalline marble, in places very pure, but usually filled with silicate minerals, to fine grained, little altered limestone, locally grading into dolomitic sandstone and shale. The color is generally white, but various shades of pink, light and deep blue, and pale green are not uncommon.

The Randville dolomite underlies a large part of the Felch Mountain district (fig. 3) and is very thick.

In the Menominee district (fig. 4) it occupies three separate belts extending in a more or less east and west direction. The formation, though dominantly dolomite, is composed of heterogeneous beds including siliceous dolomite, calcareous quartzite, argillaceous and cherty

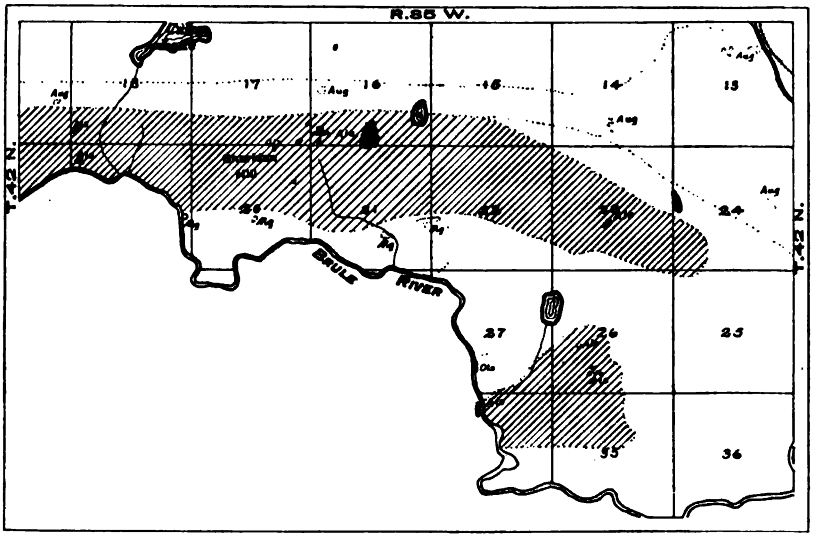

Figure 5. Map of the Saunders formation in the Iron River iron bearing district. (After R. C. Allen, Michigan Geological Survey, Publication 3).

quartz rocks. It grades downward into the Sturgeon River quartzite. The predominant phase is homogeneous, fine grained white, pink, blue, or buff dolomite. The beds vary in thickness from a few inches up to many feet. Thin veins of quartz running parallel to the bedding, anastomosing, or running irregularly through the rock mass are characteristic. The argillaceous material is in the form of light or dark gray slate and to a small extent, black slate.

Saunders formation. The Saunders* formation (fig. 5) extends across

*R. C. Allen. The Iron River District, Mon. LII, U. S. Geol. Surv. 1911, pp. 310, 311.

the southern part of the Iron River district. It is composed mainly of cherty dolomite and quartzite. Associated with these are massive white and pink dolomite, impure calcareous and talcose slates. The formation is locally much brecciated. The thickness is believed to be great but owing to folding it cannot be closely determined.

Bad River limestone. The Bad River limestone* occurs in limited areas on the Gogebic iron range (fig. 6). It is heavily magnesian and

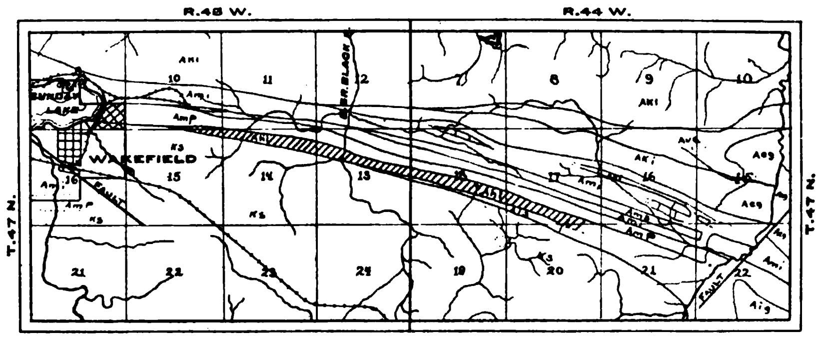

Figure 6. Map showing distribution of Bad River limestone in the east end of the Gogebic iron range. (After Van Hise and Irving, Monograph 19, U. S. Geological Survey).

locally it is nearly normal dolomite. Generally it is very siliceous, the siliceous content being in the form of chert and quartz, and to less extent silicate minerals. In places the free silica is intermingled with the dolomite and at other points it is in bands varying from a fraction of an inch in thickness to many feet.

PALEOZOIC LIMESTONES.

Geologic Occurrence.

Limestone formations occur in all of the Paleozoic systems of Michigan, except the Cambrian and Pennsylvanian. The chief limestone formations are the Beekmantown (Calciferous) including the Hermansville limestone, and the Trenton limestone of the Ordovician; the "Niagara" or Guelph and Lockport limestones, and the Monroe and Salina formations of the Silurian, the Dundee limestone, and the Traverse formation of the Devonian, and the Bayport limestone at the top of the Mississippian. Limestone horizons of minor importance occur at other points in the geological column as the Manitoulin limestone in the Cincinnati series of the upper Ordovician and the

*C. R. VanHise and C. K. Leith. The Geology of the Lake Superior District, Mon. LII, U. S. Geol. Surv. 1911, p. 228.

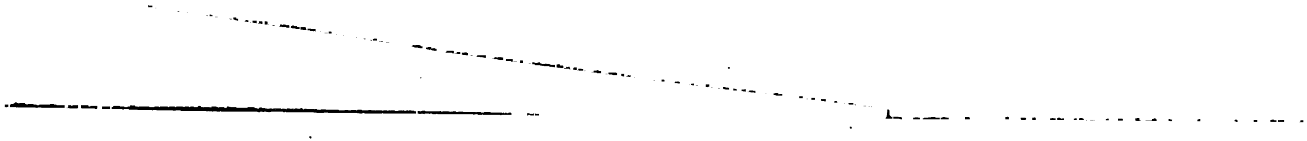

Figure 8. Geologic section across the Michigan basin from Port Rowan, Ontario, northwest to [illegible].

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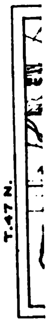

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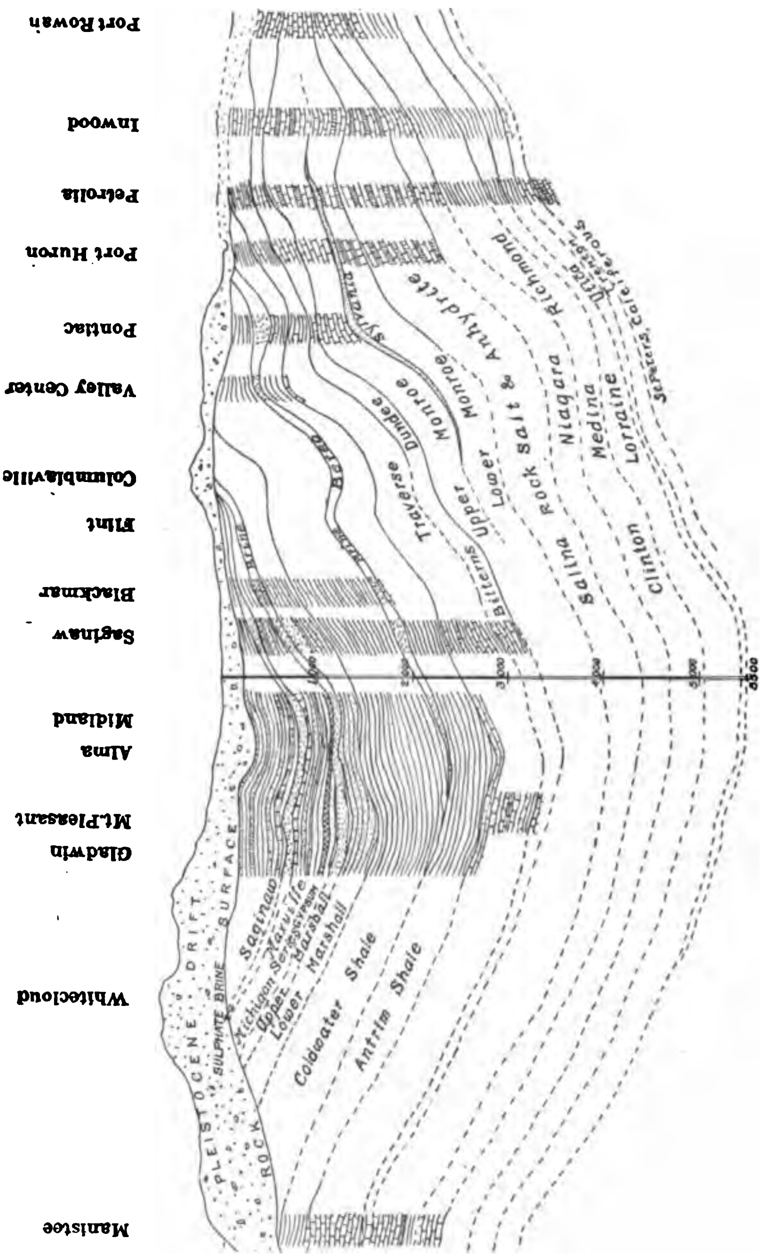

Figure 8. Geologic section across the Michigan Basin from Port Rowan, Ontario, northwest to Manistee, Michigan.

Clinton of the lower Silurian. Lenses of limestone also occur in the Michigan series in the upper portion of the Mississippian and locally in the Coal Measures of the Pennsylvanian, but these are of little or no importance.

As may be seen from the following geologic column (fig. 7) the great bulk of the limestone occurs in the lower two-thirds of the Paleozoic.

RELATION OF GEOLOGIC STRUCTURE TO AREAL DISTRIBUTION.

The Paleozoic formations in Michigan form a gigantic nest of very broad, shallow, warped basins, whose diameters decrease regularly from the bottom upward (fig. 8). Were the rocks uncovered by removing the loose surface deposits and draining the Great Lakes the rims of these basins would form concentric belts around the Coal Measures (fig. 9).

The *Michigan Basin* is a geologic province including the Southern Peninsula, the eastern part of the Northern Peninsula, the western part of Ontario, the eastern part of Wisconsin, and northern parts of Illinois, Indiana, and Ohio. The average diameter of the Basin is about 500 miles. The deepest part appears to be in Midland and Isabella counties near the geographical center of the Southern Peninsula. The total depression or depth apparently is over 7000 feet, but this is so small in comparison with the diameter that the inclination of the formations toward the center of the Basin is usually between 25 and 50 feet per mile, and rarely exceeds 60 feet.

The basin-like structure and the occurrence of the bulk of the limestone in the lower part of the rock column determine the areal distribution of the limestone formations in concentric belts near the margin of the Basin. The only extensive limestone regions in the Southern Peninsula are in the extreme northern and southeastern portions.

MARL OR BOG LIME DEPOSITS.

Many of the glacial lakes in Michigan, northern Indiana and western New York contain marl deposits. Many swamps, formerly the sites of glacial lakes, also contain marl. In some of the lakes marl formation is still being formed. Marl deposits vary in extent from a few acres up to several hundred, and in thickness from a few feet to 50 feet or more.

Marl is known to occur in 22 different counties in the Southern Peninsula, and the total area of proven deposits of workable size is over 26,000 acres.

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laceous. Locally it is very argillaceous and bituminous. Thin seams of shale are common and fine wavy laminae of shaly or bituminous matter are characteristic. In the Northern Peninsula the Trenton has three phases,* viz., (1) an upper granular, crystalline, high magnesian limestone with alternating blue and buff or brown layers terminating at the base in a dark or black bituminous limestone, (2) a middle portion of sandy or cherty layers, and (3) a basal member of blue shale and limestone, the latter being locally dark or black. In the southern part of the state where it has been penetrated in deep wells it has four well marked divisions, viz., (1) an upper, thin, dark grayish, buff and brown, high magnesian portion, (2) a thick, white to light buff, low magnesian limestone series, (3) a thick, dark, buff and brown argillaceous and bituminous series of limestones, and (4) a lower, very thick, dark gray and brown, argillaceous and bituminous series. The generally shaly and argillaceous character of the Trenton formation makes most of it unsuitable for most purposes except rough building block and crushed stone.

The thickness in the Northern Peninsula ranges from about 250 feet along Green Bay to 100 feet or less on St. Marys River. In southeastern Michigan the formation is much thicker, averaging about 850 feet.

"Niagara" Limestone.—Guelph and Lockport. The "Niagara" limestone is composed of an upper whiter and more crystalline portion called the Guelph dolomite, and a lower darker and generally less crystalline portion called the Lockport limestone, which is the Niagara proper. Since the two formations have not yet been certainly differentiated in Michigan and since quarrymen, lime burners, and lime users are habituated to the use of the term "Niagara", the name is retained in this report to include both the Guelph and the Lockport.

The Niagara limestone comes to the surface only in the Northern Peninsula. It underlies a broad belt skirting the northern shores of Lake Michigan and Lake Huron from the southern end of Garden Peninsula, Delta County, to the eastern side of Drummond Island, Lake Huron. Throughout large areas it is at or near the surface. The exposures are numerous, and owing to the hard and massive character of many of the rock layers and the gentle inclination of the strata they are usually in the form of escarpments or cuestas with steep or precipitous slopes toward the north and gentle slopes toward the south. Swamps occupy most of the depressions between the escarpments. The escarpments afford unusually favorable conditions for quarrying. The long slopes in many cases correspond to the in-

*A. C. Lane, Geological Section of Michigan, Ann. Rept. 1908, Mich. Geol. Surv., p. 48.

A. BOULDER TRACT OF ENGADINE DOLOMITE NEAR HESSEL, MACKINAC COUNTY.

These massive boulders are of characteristic occurrence in regions underlain by the Engadine dolomite.

B. A LARGE WEATHERED BOULDER OF ENGADINE DOLOMITE NEAR THE RAILROAD ONE MILE WEST OF ENGADINE, MACKINAC COUNTY.

The massive character of the boulders and the numerous drusy cavities with the peculiar concentric structures about them are characteristic of the Engadine dolomite.

clination of the beds which varies from about 40 to 60 feet per mile. The gentle lakeward dip of the strata results in shallow water for long distances off shore and an absence of good harbors. This forms a serious obstacle in the development of the numerous high grade limestone beds of the Niagara which occur some miles back from the shore

The whole formation, excepting near the base, is characterized by an absence of shaly or argillaceous material. The content of both iron and alumina is generally below one per cent, and in many beds less than one-half of one per cent. Silica, in the form of quartz sand, seams and nodules of chert, and silicified fossils, is much more abundant. Some beds are extremely cherty and siliceous, though in most of them the silica does not exceed 1½ or 2 per cent. In the Engadine dolomite at the top of the formation the total impurities are in many places less than one per cent.

The Niagara limestone is composed of at least four distinct and easily recognized members which the writer has provisionally named and defined as (1) *Engadine dolomite*, (2) *Manistique series*, (3) *Fiborn limestone* and (4) *Hendricks series.*

Engadine dolomite. The Engadine dolomite is the name proposed for the upper member of the Niagara. It is best exposed in the vicinity of Ozark, Mackinac County, but because this name was already preoccupied in geologic literature the member was named from the village of Engadine, where it is exposed over a large area about one mile west of the village. The Engadine dolomite is an extremely massive, hard, and very crystalline dolomite, distinctly bluish or mottled and streaked with blue. It is also characterized by numerous druse cavities more or less completely filled with crystals of dolomite or pearl spar. The stone is very poorly and massively bedded, and except where greatly weathered shows very few distinct bedding planes. The joint systems are generally poorly developed and very irregular. It forms a strong, though broken, northward facing escarpment nearly the entire distance from Seoul Choix Pt., Schoolcraft County, to St. Marys River. Areas where this formation is exposed or near the surface are covered with great boulders as at Ozark, Engadine, Hessel and Garnet. (Pl. I, A and B).

Owing to its highly crystalline character and bluish colorations the Engadine dolomite is known locally as marble. This resemblance to marble resulted in considerable core drilling near the mouth of Bulldog River, Schoolcraft County, in an attempt to prove up a marble deposit. The color, however, is not permanent. Upon exposure to the weather for a year or two the bluish color changes to a light buff or brown. The writer has seen stone in which the color had been completely

altered to the depth of more than an inch, though the stone had been quarried but two years. Those parts of the stone which are free from druse cavities undoubtedly would make good building block, but it would be an unsatisfactory substitute for marble.

The Engadine beds are uniformly normal dolomite, almost free from impurities. The exceptional purity of the dolomite makes it especially adapted for basic linings in open hearth furnaces and for paper manufacture with the sulphite process.

The dark argillaceous dolomites of the Monroe-Salina apparently overlie the Engadine dolomite but nowhere have the two been seen in contact. The contact with fossiliferous beds of the underlying Manistique series is sharp and well exposed along a high bluff about two miles north of Ozark. At this point the thickness, which is the maximum observed anywhere, is about 54 feet. The surface of the bluff has suffered severe glacial erosion, therefore the normal thickness of the formation is presumably considerably more than this.

In southeastern Michigan and southwestern Ontario the same bluish, highly crystalline dolomite occurs directly beneath very dark argillaceous dolomite apparently belonging to the base of the Salina. The thickness of the bluish crystalline dolomite in the H. R. Ford well at Dearborn, Wayne County, is about 95 feet.

Manistique series. The Manistique series is a thick succession of dolomite and high magnesian limestones extending from the base of the Engadine dolomite downward to the top of the Fiborn limestone.

It comprises a great variety of dolomites and generally high magnesian limestones, differing greatly in color, texture, and structure. The color varies from pure white, light gray and buff to blue, dark gray, and buff or brown, the texture from earthy or finely crystalline to coarsely crystalline. Some of the strata are massive but others are thin bedded. The jointing varies from regular to very irregular. Many of the beds are very fossiliferous but some contain no fossils. Favosites, Halysites, and Syringopora are conspicuous among the corals, though many other forms are abundant. *Pentamerus oblongus* is a most conspicuous form among the brachiopods. Two to three miles north of Engadine the beds are extremely fossiliferous. Some are a mass of corals and bryozoa and others a mass of brachiopods. Apparently this region was the site of extensive reef building in Niagaran time.

Many of the beds are very dense, finely banded or laminated, and break with a pronounced conchoidal fracture. The fine banding is beautifully brought out through weathering and the term "ribbon limestone" is often given to such rock. Some beds are very granular and resemble sandstone.

The percentage of iron and alumina, though generally higher than in the Engadine dolomite, is usually low. The silica, however, is apt to be high and some of the beds are extremely cherty and siliceous.

Formerly the limestones of this series were much used for burning lime, but now they are utilized for lime only at Manistique. Some of the stone is burned only with great difficulty. The great difference in chemical composition and physical qualities between the different beds in most quarries generally necessitate hand sorting. The hardness and toughness of much of the stone, combined with ease of access, lend value to this formation for road making and concrete.

The series is widely exposed, particularly in the vicinity of Manistique and along the west side of Garden Peninsula where there are bluffs rising nearly vertically from 100 to over 230 feet above Big Bay de Noc, also near Gould City, north of Engadine, southeast of Trout Lake, at Rockview, and at many places on Drummond Island. From Manistique northwest to Indian Lake and beyond there is an almost continuous succession of small roughly parallel and nearly E-W escarpments facing north with gentle back slopes toward the south. The northern limit of the exposures of this series, like that of the Engadine dolomite, is generally marked by a pronounced though much broken escarpment. In places the escarpment rises 100 to 150 feet or more above the level of the swamps to the north.

The thickness of the series is uncertain but it is over 250 feet as shown by the section at Burnt Bluff, Garden Peninsula. The contact with the Engadine dolomite above is well exposed at several places but the contact with the Fiborn limestone below was observed only in the Hendricks quarry where in places five or six feet of light colored magnesian limestone rests directly on the Fiborn.

Fiborn limestone. In practically all of the geological literature the Niagara limestone is described as a dolomite formation. Rominger* who made an early study of the Niagara found only very thin and insignificant beds of high calcium stone. Some time prior to 1901, Dr. A. C. Lane† visited some caves in limestone on sections 15, 16, 21 and 22, T. 44 N., R. 7 W. This limestone proved to be low in magnesia and some years later quarrying operations were begun at the site of the present Fiborn quarry. Deposits of high calcium limestone were discovered at other places to the west and two other quarries, now known as the Blaney and Hendricks were opened.

In 1913 the writer found that the Fiborn limestone is exposed at many places in several areas of considerable size in an arcuate belt (fig. 9) which extends from a point (cen. S. line of sec. 2, T. 42 N., R. 14 W.)

*C. Rominger, Paleozoic rocks, Vol. I, Pt. III, p. 37, Mich. Geol. Surv., 1869.
†Ann. Rept. Mich. Geol. Surv. 1905, Limestone, p. 20.

four miles north of Whitedale, Schoolcraft County, eastward to Gould City, Mackinac County, thence northeast to Hendricks quarry (sec. 1, T. 44 N., R. 9 W.) and thence southeast through Fiborn quarry (secs. 16 and 21, T. 44 N., R. 7 W.) to within two or three miles of Trout Lake. Westward from section 11, T. 42 N., R. 14 W., the bed disappears beneath the swamps north of the prominent escarpment of the Manistique series, along the Manistique River and its branches, and the streams running into Indian Lake. Eastward from Trout Lake the bed disappears beneath the lake clays of Mackinac and Chippewa counties. On Lime Island, St. Marys River, the drift is filled with angular fragments of the Fiborn stone, indicating its presence in that immediate vicinity. Apparently the bed crosses Drummond Island from the vicinity of Maxton southeast toward Marblehead. It is possible that a three foot bed of fine grained, ash colored, high calcium* limestone in the lower portion of the Marblehead section is the diminished representative of the Fiborn bed.

The largest area of exposures is in the vicinity of Blaney quarry, Gould City, and the Hendricks and Fiborn quarries. Blaney quarry is located near the west end of an area of almost continuous exposures over a mile in width extending from about the middle of section 4, T. 42 N., R. 13 W., eastward about five miles nearly to Lake Ella. About a mile west of Gould City the area in which Fiborn stone is exposed, or near the surface, is apparently more than a square mile in extent. In the vicinity of Hendricks and Fiborn quarries exposures are said to extend over an area of two to three square miles. The Fiborn bed is exposed, or is at shallow depths, at several other places, notably four miles north of Whitedale, five miles north of Engadine, two or three miles northwest of Trout Lake, and between Fiborn and Hendricks quarries.

The Fiborn limestone beds are buff to grayish buff dense grained to lithographic limestone generally containing small disseminated crystals of calcite. The lithographic texture is very marked in some beds but small crystals of calcite apparently render nearly all of the stone of no value for lithographic purposes. It is possible that certain thin strata may be found sufficiently free from crystals to yield moderate sized slabs suitable for lithographic work.

The stone is mainly massive though locally it is markedly laminated and well bedded. The joint systems are very irregular and poorly developed. The stone is brittle and breaks with a perfect conchoidal fracture, forming fragments with sharp points and edges. The lithographic texture, numerous small calcite crystals, and perfect conchoidal fracture are features which make field identification of the Fiborn

*C. Rominger, Vol. I, Pt. III, p. 35, Mich. Geol. Surv. 1873.

beds easy and unmistakable. Moreover, the stone calcines easily and, wherever forest fires have passed over it, the surfaces of the exposures and field boulders are pure white in contrast to the grayish or yellowish white of partially burned stone from other beds.

The Fiborn bed is very uniform in composition and generally the content of calcium carbonate is between 94 and 97 per cent. The silica varies usually from 0.75 to 1.50 per cent, and the iron and alumina from 0.25 to 0.75 per cent. Magnesium carbonate, except near the bottom of the bed, is usually below 2 per cent, though locally it may exceed 3 or 4 per cent. The bottom portion in most places contains from about 2 per cent to 5 per cent, or even more of magnesium carbonate. Owing to its purity and freedom from magnesia the Fiborn limestone is quarried extensively for blast furnace flux, carbide, sugar manufacture, and hot lime. Though very brittle the stone makes very satisfactory road material on account of its high cementing power.

The thickness of the member varies from 18 to about 30 feet. The maximum thickness developed in the Blaney quarry is about 26 feet. Eastward this decreases to only about 18 feet at the Hendricks quarry but still farther east the bed thickens to nearly 30 feet in the Fiborn quarry. If the thin bed of high calcium acicular stone in the Marblehead section, Drummond Island, is the representative of the Fiborn bed it has shrunk to only about three feet in thickness. In one of the Manistique wells 27 feet of "white limestone" was penetrated between 80 and 107 feet in depth and this may be the Fiborn bed. It is a significant fact that although the lower portion (Lockport) of the Niagara is well exposed on Manitoulin Island in Ontario no trace of a high calcium bed has been observed. The same may be said for the western extension of the Niagara in Wisconsin. In the H. R. Ford well at Dearborn which completely penetrated the Niagara, no trace of high calcium stone was found though samples were taken every five feet. This would indicate that the Fiborn bed is a lens in the Niagara and largely confined to the limits of the Northern Peninsula.

Hendricks series. In the floor of the Hendricks quarry of the Union Carbide Company a test pit has been sunk to the depth of about 20 feet and test holes have been drilled in the vicinity of the quarry to the depth of over 145 feet. The beds in the test pit range in composition from high calcium limestone to normal dolomite, and according to the analyses of the drill cores the strata down to 145 feet and perhaps deeper are composed of the same alternating series of high calcium, and low to high magnesian limestones. As far as known none of these strata are exposed anywhere else except in the vicinity of the Manistique lakes and apparently at Marblehead, Drummond Island. The

writer, however, has not visited these localities, hence must rely upon the older descriptions given by Rominger. Other exposures probably occur on some of the islands in St. Marys River and Potagannissing Bay.

The bed immediately underlying the Fiborn limestone at Hendricks quarry is a very white crystalline limestone containing from 2 to 5 per cent of magnesia. In the Blaney quarry of the White Marble Lime Co. this bed is said to contain only about 85 per cent of calcium carbonate. At Fiborn also it contains considerable magnesia. At Hendricks quarry the white limestone is directly underlain by one foot of dark lithographic limestone containing only about one per cent of magnesia. The next lower bed, 2 feet thick, is higher in magnesia and the next two, together 8 feet thick, are practically normal dolomite. Next follows one foot of high calcium stone which gives place to heavy magnesian limestone which forms the floor of the pit. According to the analyses of two drill cores from the vicinity of Hendricks quarry the magnesian zone below the Fiborn bed is between 13 and 14 feet thick, therefore the floor of the test pit must be near the bottom of the zone. The magnesian zone is followed by a series of high calcium limestones 30 to 50 feet in thickness. Below this there are low magnesian limestones down to 145 feet, the bottom of the deeper hole.

According to Rominger the exposures on Manistique lakes are highly magnesian and also most of the strata at Marblehead, Drummond Island.

The writer has provisionally termed the series of limestones and dolomites from the base of the Fiborn limestone down to the Rochester shale, the *Hendricks series*. Further field work and faunistic studies, however, may show that the Fiborn limestone should be included in this series. The belt underlain by the Hendricks series lies directly north of the belt of Fiborn exposures and almost wholly in a heavily drift covered area, hence the conditions for detailed study are very unfavorable.

The thickness of the Hendricks series is uncertain but it is certainly over 100 feet as shown by the drill holes near Hendricks quarry.

Salina formation. The Salina formation has not been definitely recognized in outcrops in Michigan. In St. Ignace peninsula it may be some part of what is now mapped and described as the Monroe formation.

Monroe formation. The Monroe formation is exposed in southeastern Michigan and in St. Ignace peninsula and adjacent islands. In Monroe county the following subdivisions are now recognized*:

*W. H. Sherzer and A. W. Grabau. The Monroe Formation, Pub. 2, Geol. Ser. 1, Mich. Geol. and Biol. Surv. 1909, pp. 27-54.

1. Upper Monroe or Detroit River series.	Lucas dolomite	200 ft.+
	Amherstburg dolomite	20 ft.
	Anderdon limestone	40 ft.
	Flatrock dolomite	60 ft.
2. Sylvania sandstone and dolomite.		
3. Lower Monroe or Bass Island series.	Raisin River dolomite	200 ft.
	Put-in-Bay dolomite	100 ft.
	Tymochtee shale	90 ft.
	Greenfield dolomite	100 ft.

These subdivisions, however, have not been recognized in the Monroe formation in St. Ignace peninsula and adjacent islands and apparently the three primary divisions are clearly developed only in southeastern Michigan in Monroe County and along Detroit River. North and northwest from this region the Sylvania sandstone grades into dolomite, though here and there in the state borings show the presence of a sandstone at about the horizon of the Sylvania.

Lower Monroe or *Bass Island series.* The Lower Monroe series is composed chiefly of gray argillaceous dolomite with some shale, gypsum, and celestite. Only the upper member, the Raisin River dolomite, is exposed in Monroe County. It is composed of gray, fine grained argillaceous dolomite and subordinate amounts of öolite. The dolomites are generally thin bedded, in places bituminous and more or less shattered and brecciated. There are several öolitic beds, each being underlain by a peculiar bed of fine grained, blotched, mottled, and streaked dolomite. The markings are of a distinct bluish cast, but where weathered they are rusty brown, indicative of the presence of iron. The more massive blue portions near the bottom of this bed are very shaly.

The brecciation of the Monroe dolomite is a very general characteristic. The most conspicuous occurrences are in St. Ignace peninsula, on Mackinac Island, and in the vicinity of Monroe, Monroe County. Brecciated horizons have been struck in many wells penetrating the Monroe in different parts of the state.

The brecciation is of two types.* The first is a complete shattering of the formation, producing a breccia, the fragments of which are firmly held in a matrix of finer materials completely cemented. The second is more local and affects individual beds only. The blocks in this type are locally more or less disturbed but only slightly displaced, where in the first type the breccia is composed of a mixture of fragments of several different beds showing considerable displacement.

*W. H. Sherzer and A. W. Grabau. The Monroe Formation, Pub. 2, Geol. Ser. 1, Mich. Geol. and Biol. Surv. 1909, p. 29.

The cause of the brecciation is a mooted question. Lane* ascribes the regional type to the inrush of great tides across shallow flats, but Grabau† argues that it represents the talus breccia produced on an extensive land surface of post Monroe time and that this talus was incorporated into the lower Onondaga on the resubmergence of this region by the sea, or that it was produced by solar fluxion. The local brecciation is apparently due to buckling produced by some expansional force such as might arise when anhydrite by chemically combining with water is transformed into gypsum.

The Raisin River dolomite is exposed at many places in eastern Monroe County, particularly in the vicinity of the river from which the member takes its name. In the early days the stone was extensively burned for lime but owing to its argillaceous character, the exhaustion of suitable fuel, and competition of limes of better quality, the industry in this region ceased many years ago. Many small quarries were formerly operated, supplying Detroit with crushed stone chiefly for concrete and macadam, but now only two or three quarries are in operation. The stone is too impure and highly magnesian for chemical purposes and the argillaceous content or its brecciated character makes it locally unfit even for concrete, macadam or ballast.

Upper Monroe or *Detroit River series*. The Upper Monroe or Detroit River series is exposed along Detroit River and at several places in the western part of Monroe County.

The Flat Rock, Amherstburg, and Lucas members are high magnesian limestones or dolomites, but the Anderdon is a very pure high calcium limestone. The dolomites are gray to brown, argillaceous or bituminous, and locally brecciated. Formerly several quarries were operated in the Upper Monroe dolomites, but during the past few years only two or three have been in operation and these but intermittently. The argillaceous and highly magnesian character of much of the stone makes it unsuitable for most purposes. The Anderdon limestone is exposed in the Anderdon quarry on the Ontario side of Detroit River and also in the lower part of Sibley quarry where, due to erosion of the Lucas and Amherstburg dolomites, it directly underlies the Dundee and is quarried with it. The Anderdon is present only in patches, having been largely removed by erosion.

In places the Anderdon limestone is practically pure calcium carbonate and its generally low content of magnesium carbonate makes it particularly suitable for chemical purposes.

In the St. Ignace peninsula and adjacent islands the Monroe formation

*A. C. Lane, Vol. V, Mich. Geol. Survey 1895, pt. 2, p. 27.
†A. W. Grabau. The Monroe Formation, Pub. 2, Geol. Ser. 1, Mich. Geol. and Biol. Surv. 1909, p. 29.

is characterized by much brecciation and contains beds of gypsum. The argillaceous and magnesian character of the breccias and their tendency to disintegrate under weathering, make them valueless. Formerly they were utilized locally for burning lime.

Dundee (Onondaga) limestone. The Dundee limestone is a widespread formation and underlies nearly all of the Southern Peninsula, but it comes to the surface only in a narrow belt in the southeastern part of the Peninsula and along the shore of Lake Huron from Mackinac City, Cheboygan County, to Presque Isle, Presque Isle County. Its outcrop elsewhere is buried under surface deposits or lies beneath the waters of Lake Michigan and Lake Huron.

The Dundee is chiefly high calcium limestone with some magnesian beds near the base of the formation where it rests directly on the Monroe dolomites. It is generally gray to buff or brown, crystalline, bituminous, and locally very fossiliferous. Locally some of the beds average over 98 per cent of calcium carbonate. Its purity and freedom from magnesia renders the Dundee limestone especially valuable for chemical purposes, soda ash products, flux, carbide, etc. It is quarried very extensively near Detroit and Rogers City. The bituminous content renders much of the stone unsuitable for lime burning.

The Dundee formation averages about 100 feet thick in the southeastern portion of the Southern Peninsula and over 200 feet in the northern part. In the central part where penetrated by borings it is over 250 feet thick, but on the western side of the state it is very thin and in places, as at Muskegon, perhaps absent.

Though the areal extent of the exposures of the Dundee is small in comparison with most of the other limestone formations, it is one of the most economically important and furnishes nearly half of the annual output of limestone.

Traverse (Hamilton and Marcellus) formation. The Traverse formation is widely exposed throughout a curving belt extending from Little Traverse Bay, Lake Michigan, to Thunder Bay, Lake Huron. Southwest from Little Traverse Bay to Benzie County the formation is generally deeply drift covered. It occupies a narrow belt in southeastern Michigan but it is not exposed there. Generally speaking, it is a series of limestones and shales with a heavy shale (Bell or Marcellus) at the base. In the southern part of the state the formation is dominantly shale. In the Alpena district, however, limestone is dominant and in the Little Traverse Bay region the formation is almost wholly limestone, containing only a few relatively thin beds of shale, excepting the Bell shale at the base. The limestone varies

greatly in color, texture, and composition. The color varies from pure white to gray, buff, brown, and black, and the texture from very fine grained or lithographic to coarsely crystalline. Some of the strata are very thin bedded, others massive. In general the jointing is very regular. The formation as a whole is richly fossiliferous, many strata being composed of a mass of brachiopods, corals or bryozoans. In the Alpena district large reefs of corals, many of them chiefly of Acervularia, are characteristic. The limestone varies in composition from practically pure calcium carbonate to heavy magnesian limestone or normal dolomite. There are also all gradational phases between limestone and shale. Most of the shale is very calcareous and generally very soft. Under the drill it churns up into a "soapy" mass, hence it is generally reported by drillers as "soapstone." The gray color is generally due to the argillaceous content and the black color to a large amount of bituminous matter. Some of the shaly limestone is also extremely cherty. Along Little Traverse Bay much of the limestone is yellow, buff, or brown, which is due to the oxidation of the iron content. The limestone here is generally much more magnesian than elsewhere.

In the Alpena district the Traverse has been subdivided by Grabau* into the following members:

1. Thunder Bay series.
2. Alpena limestone.
3. Long Lake series.
4. Bell shale.

The Long Lake series is chiefly shale and thin bedded limestone, some of the limestone being very argillaceous. This series forms a belt extending from Stony and Partridge points northwest along Thunder Bay river. Owing to its generally shaly or argillaceous character the series apparently is of little value except for manufacture of cement.

The Alpena limestone is chiefly high calcium limestone and is characterized by the presence of an extensive system of coral reefs. The reefs, being more resistant to erosion than associated strata, form a network of low ridges on the surface in the vicinity of Alpena. The Alpena limestone as a whole is more massive and resistant than the Thunder Bay series above or the Long Lake series below and forms an elevated tract several miles wide extending northwest from the head of Thunder Bay between Long Lake and the North Fork of Thunder Bay river into Presque Isle county. Apparently the elevated tract extending through Metz and Larocque toward

*A. W. Grabau. The Stratigraphy of the Traverse Formation, Ann. Rept. 1901, Mich. Geol. Surv., pp. 163-196.

Onaway is also due to this hard limestone series. The reef limestone is generally very free from magnesia and impurities. In some places the calcium carbonate averages over 99 per cent. Locally, however, the reefs have been heavily dolomitized. These areas are known as dolomite or magnesian ''chimneys.'' The beds dip away from the reefs at rather steep angles but at a relatively short distance they become practically horizontal. The beds extending horizontally between the reefs are chiefly high calcium limestone with some magnesian limestone, shale, and shaly chert, and very bituminous limestone. In large quarrying operations the presence of these undesirable beds generally results in a large percentage of waste in the quarry product. At Alpena the Huron Portland Cement Company utilize this waste product in the manufacture of Portland cement.

According to Grabau* the Alpena Limestone is only 35 feet thick, but in the quarry of the Michigan Alkali Company, Alpena, the high calcium strata and coral reefs have been quarried to the depth of 80 feet or more. Several drill holes northwest of Alpena also show that the thickness of the high calcium strata is much greater than that given by Grabau. Since by definition the name refers to the ''Middle Limestone'' lying between the shales and limestones of the Thunder Bay series above and of the Long Lake series below, the term should include the entire limestone series exposed in the Michigan Alkali quarry down to the argillaceous limestone beneath. This would give a thickness of about 80 feet for the Alpena or ''Middle'' limestone. Due to its generally high calcium content and its numerous exposures the Alpena limestone is of much more economic importance than the other members of the Traverse formation in northeastern Michigan. The many large exposures with favorable quarrying conditions form an immense reserve of high calcium limestone. Only those in the vicinity of Alpena near cheap water transportation have been developed successfully.

In the Little Traverse Bay region exposures are largely confined to a double line of bluffs along the south shore of the bay. The first line of bluffs is close to the shore and varies in height from 10 to 40 feet or more. The second line is generally from a few hundred feet to a half mile from the shore and varies from a few feet to about 50 feet in height.

Quarrying operations and well borings show that in this region the Traverse formation is almost wholly limestone down to depths of 350 to 475 feet. An upper bed of shale 6 to 10 feet thick has been encountered in some of the quarries and another bed has been struck in wells at about 250 feet. Thin partings of shale from a fraction of an inch up to 6 inches, however, are characteristic of much of the lime-

*A. W. Grabau, Ann. Rept. 1901, Mich. Geol. Surv., p. 174.

stone exposed in the quarries. Thus the formation changes from an alternating series of limestone and shale in the Alpena district to almost solid limestone in the Little Traverse Bay region. As exposed along the shore of the bay the series consists of an upper, yellow to brown, friable, high calcium limestone 15 feet or more thick, a middle, yellow to brown, friable and more or less completely dolomitized limestone about 40 feet thick, and a lower, gray, dense grained or lithographic to crystalline, high calcium limestone, apparently more than 40 feet thick.

The Traverse formation is widely exposed in Presque Isle county and exposures are also numerous in the central portion of Cheboygan county. The limestone is generally high calcium though there are some highly magnesian beds. Many of the strata are shaly, bituminous, and fossiliferous. The texture varies from dense grained or lithographic to very crystalline. The subdivisions of the Traverse easily recognizable in the Alpena district do not appear to be clearly defined in Cheboygan county and the western part of Presque Isle county. Apparently these limestones represent the transition from the limestones and shales of the Alpena district to the solid limestone of the Little Traverse Bay region.

In the northern and central parts of the state the Traverse averages from 600 to 650 feet thick, including 50 to 80 feet of shale at the base. Along St. Clair River it is only about 300 feet thick and in the extreme southern and southwestern portions of the state it is generally less than 100 feet thick.

The Traverse probably contains a larger amount of high calcium limestone than any of the other formations within the state and, owing to the number of and extent of its exposures, it also contains a larger amount of available high calcium limestone. Unfortunately the exposures are all in the northern part of the state and largely inland. Only in the vicinity of Thunder and Little Traverse bays are deposits of the higher grade limestone near cheap water transportation. Moreover, the limestone contains interbedded shales or shaly limestones and magnesian strata, which make development difficult and uncertain. Notwithstanding these unfavorable factors the Traverse formation is second only to the Dundee in economic importance and the inland deposits of high calcium stone form an enormous reserve for future use.

Bayport (Maxville) limestone. The Bayport limestone is the upper member of the Grand Rapids group of the Mississippian system. It underlies a belt around the central Coal Basin excepting on the southeast where it has been largely removed by erosion. The chief areas of exposures are in the vicinity of Bayport in Huron county, in Arenac

County, and near Bellevue, Eaton county. In Jackson county the Bayport limestone forms a capping on many of the pre-Coal Measure hills.

The formation consists of white to light gray and bluish limestone, locally very cherty and sandy, very calcareous sandstone and pure sandstone. The limestone varies from high calcium to high magnesian. Owing to its cherty or sandy character much of the limestone is suitable only for concrete or road metal. The high calcium beds are thin and only locally are sufficiently thick and pure to warrant development. At Bellevue, Eaton county, a high calcium bed from 12 to 15 feet thick, is utilized with the underlying shale for the manufacture of Portland cement.

CHAPTER V.

DISTRIBUTION, CHARACTER, AND DEVELOPMENT OF LIMESTONE DEPOSITS BY COUNTIES.

PRE-CAMBRIAN LIMESTONES,

Dickinson County.

Distribution. The Menominee Iron District of Michigan extends across the southern portion of Dickinson county. The Randville dolomite (Fig. 4) forms three distinct* belts roughly parallel with the longer axis of the district. The northern belt extends from section 11, T. 40 N., R. 30 W., southeast into section 10, T. 39 N., R. 28 W., where it is buried under Cambrian sandstone,—a distance of about 12 miles. The dolomite is exposed at only a few places. The middle belt begins just north of Lake Antoine in section 20, T. 40 N., R. 30 W., and extends east-southeast between Indiana and Cuff mines to Iron Hill in section 33, T. 40 N., R. 29 W., a distance of nearly seven miles. The exposures in this belt are large and very numerous. The southern belt extends from the Menominee River to Waucedah, at the east end of the district,—a distance of over eighteen miles. From Menominee River east to Sturgeon River the dolomite forms a range of high hills broken only at a few points. The tops of the higher hills are capped with Cambrian sandstone. Some of the exposures in the belt are very large. East of Waucedah the Randville dolomite is covered by Paleozoic rocks.

The Felch Mountain range† (fig. 3) is a belt, usually less than a mile wide, which extends in an E-W direction through the southern portion of T. 42 N., Rs. 28, 29, and 30 west, a distance of over 13 miles. The Randville dolomite underlies a large part of the range. The formation is well exposed in the vicinity of Randville, from which it takes its name and also in the vicinity of Felch Mountain.

In section 26, T. 42 N., R. 28 W., at the extreme eastern end of the range, the Northern Michigan Marble Company made an unsuccessful

*C. R. VanHise and C. K. Leith. Geology of the Lake Superior Region. Mon. LII, Geol. Surv. 1911, pp. 333-334.
†Mon. LII, U. S. Geol. Surv. 1911, p. 302; also H. L. Smyth, The Felch Mountain Range Mon. 36, U. S. Geol. Surv., 1899, pp. 374-426.

attempt to quarry marble. The Commissioner of Mineral Statistics of Michigan describes the deposit as follows: "Some of it is pure white, some variegated, shading from white to pink, green, gray, and purple, making beautiful slabs for wainscoting and interior work. It is somewhat granitic in nature; sufficiently so that the tests given foreign and New England marbles will not tarnish the highest polish. It is susceptible of a polish almost equal to onyx."

The Sturgeon River district* (fig. 3) occupies the western portion of T. 42 N., R. 27 W., and the central and northern portions of T. 42 N., Rs. 28, 29, and 30 W. The area of Randville dolomite occurs on the opposite limbs of a syncline which pitches to the northwest. The north arm extends from the western part of section 2, T. 42 N., R. 28 W., northwest into sec. 23, T. 43 N., R. 29 W., a distance of over six miles. The south arm extends slightly south of west into sections 9 and 16, T. 42 N., R. 30 W., a distance of over 14 miles. Exposures are few in number and both limbs of this fold disappear beneath a thick drift cover.

Character. The Randville formation is dominantly dolomite but contains a variety of other beds, including quartzite, slate, cherty quartz rocks, and corresponding gradational phases. The Randville grades downward into the underlying Sturgeon River quartzite. It is also cut by veins of quartz.

The dominant phase of the Randville dolomite is massive, homogeneous, fine grained, white, pink, blue, and buff dolomite, but even the purest beds contain interstratified siliceous quartzite and vein quartz. The abundance of vein quartz indicates extensive fracturing and crushing, followed by cementation resulting in many places in a breccia of dolomite fragments with a siliceous matrix. Owing to its generally siliceous and argillaceous character the dolomite is unsuitable for most purposes excepting crushed stone and building stone.

Locally the dolomite has been more or less completely altered to marble and attempts have been made to exploit it for this purpose but apparently the impurities and the unfavorable jointing renders it unsatisfactory.

An analysis by Geo. Steiger† of the ferruginous phase of the Randville dolomite from Hamburg Hill in Dickinson County is given below:

*Mon. LII, U. S. Geol. Surv. 1911, p. 300.

†Bull. 591, U. S. Geol. Surv. Analysis of Rocks and Minerals from the Laboratory of the U. S. Geol. Surv. 1880 to 1914, p. 236.

Analysis of Randville dolomite.

	No. 1.
SiO_2	36.71
Al_2O_3	5.34
Fe_2O_3	.35
FeO	3.37
CaO	15.11
MgO	10.78
Na_2O	.12
K_2O	2.40
H_2O −	.55
N_2O +	1.61
TiO_2	.27
CO_2	23.22
P_2O_5	.05
MnO	.23

The following test made by the Office of Public Roads, Department of Agriculture, Washington, D. C., shows that it is considerably harder than the average limestone but lower in toughness and cementing value:

Locality.	Weight lbs. per cu. ft.	Absorption lbs. per cu. ft.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
Iron Mountain	178	0.40	4.06	8.6	19	8	25

Gogebic County.

Distribution. The Gogebic Iron Range extends from the Wisconsin line eastward to Gogebic Lake. The Bad River limestone* (fig. 6) is present only in a narrow belt from the northeastern corner of section 15, T. 47 N., R. 45 W., about one mile east of Sunday Lake, E-SE to section 22, T. 47 N., R. 44 W., a distance of about six miles.

Character. The Bad River limestone is heavily magnesian and locally approaches normal dolomite. It contains impurities in the form of silicate minerals such as tremolite, chlorite, and sericite, and free silica, in the form of quartz and chert. The free silica is partly intermingled with the dolomite and partly occurs in bands varying in thickness from a fraction of an inch up to many feet. The siliceous bands stand out in relief on weathered surfaces. The entire formation has been metamorphosed and thoroughly recrystallized. The texture ranges from fine† to coarse, and the color, from white to gray. The dolomite has no present industrial value. The following analysis by W. F. Hildebrand of the U. S. Geological Survey shows the siliceous and heavy magnesian character of the limestone.

*C. R. VanHise and C. K. Leith. Geology of the Lake Superior District, Mon. LII, U. S. Geol. Surv. 1911, p. 228.

†R. D. Irving and C. R. VanHise. The Penokee Iron Bearing Series of Michigan and Wisconsin, U. S. Geol. Surv. 1892, p. 130.

Analysis of Bad River Limestone.

Analysis No.	Location.	SiO_2.	Fe_2O_3.	FeO.	$CaCO_3$.	CaO.	$MgCO_3$.
2	Sunday Lake S. E. ¼, Sec. 18, T. 47 N., R. 44 W..........	3.07	.09	.86	....	29.72	....

Analysis No.	Location.	MgO.	H_2O.	CO_2.	Cl.	Total.
2	Sunday Lake, S. E. ¼, Sec. 18, T. 47 N., R. 44 W.........	19.95	.30	45.31	trace	99.45

Iron County.

Distribution. In the Iron River Iron District the limestone formation is known as the Saunders formation and in the Crystal Falls Iron District, the Randville dolomite.

In the Iron River District the Saunders formation* (fig. 5) occurs in a belt of varying width across the southern part of the district in a general direction a little north of west. It is well exposed at Sheridan Hill in sec. 20, T. 42 N., R. 35 W. and vicinity. The belt owes its altitude to the more resistant character of the Saunders formation.

Character. Cherty dolomite is dominant but the formation also includes beds of massive white and pink dolomite, quartzose dolomite, impure carbonate slates, quartzites, and talcose slates. The rock is exceedingly brecciated in the vicinity of Sheridan Hill and crushed and fractured cherty fragments are imbedded in the greatest confusion in secondary infiltrated silica and carbonate, silica being dominant. In the Saunders ridge masses of almost pure quartz are associated with pure massive white dolomite and banded chert and cherty dolomite. Due to their more resistant character, the chert bands stand out prominently on weathered surfaces and give a ribbed appearance to the rock. Every gradation from dolomite to pure silica may be observed but generally when the chert content becomes important it shows a tendency to segregate from the dolomite in bands.

Analysis No. 3 by Prof. A. C. Clark of the Michigan Agricultural College is of the purer phase of the dolomite and No. 4 is of a typical specimen from the ferruginous dolomitic slate phase.

*R. C. Allen, The Iron River District. Monograph LII, U. S. Geol. Surv. 1911, p. 310; also Publication 3, Geol. Ser. 2, Michigan Geol. Surv. 1910, The Iron River Iron Bearing District of Michigan, pp. 36-44.

Analyses of Saunders Dolomite.

	3.	4.
SiO_2	6.10	25.3
Fe_2O_3	.49	3.25
Al_2O_3		13.78
FeO		2.93
CaO	29.33	17.28
MgO	19.98	7.86
MnO		trace
CO_2	43.90	24.50
Na_2O		.42
K_2O		2.68
N_2O	.07 (at 105°)	2.04
H_2O	.05 (at 115°)	

Distribution. In the Crystal Falls district the Randville dolomite (fig. 2) completely surrounds a large oval or dome like anticline of Archean rocks northeast of the city of Crystal Falls. The longer diameter of the oval has a general N-NW direction. The formation is exposed on the east side of this fold in the vicinity of Michigamme Mountain, sec. 10, T. 43 N., R. 31 W., and northwest into sec. 19, T. 46 N., R. 32 W., a distance of nearly 18 miles. On the west side of the fold the dolomite is not well exposed. On the east the belt is about a half mile wide and the thickness of the dolomite is about 1500 feet.

Character. The formation ranges from coarse "sugary" marbles, in places very pure, but usually filled with secondary silicate minerals, to fine grained, little altered limestones, which locally grade into dolomitic sandstones and shales. The usual colors are white but various shades of pink, light and deep blue, and pale green are not uncommon. Some of the varieties are oolitic.

Analyses No. 5, 6, and 7, by R. J. Forsyth, are of Randville dolomite from the Michigamme Mountain region. Nos. 8, 9, and 10, by G. B. Richardson are of samples from localities unknown. No. 8 represents the pure dolomite, Nos. 5 and 6 the slaty phases, and No. 10 siliceous dolomite.

Analyses of Randville dolomite.

	5.	6.	7.	8.	9.	10.
Insoluble in HCl	14.25	9.34		2.0	9.7	29.1
Fe_2O_3, Al_2O_3	11.15	12.57	5.38	1.2	2.1	2.1
$CaCO_3$	47.18	45.98	36.60	53.2	48.9	39.3
$MgCO_3$	18.48	19.22	16.36	42.3	38.0	27.7
Total				98.7	98.7	98.3

This formation is suitable only for road metal and ballast.

Marquette County.

Distribution. The Kona dolomite* of the Marquette Iron District takes its name from the Kona hills east of Goose Lake. It forms a westward facing U (fig. 1) in the eastern part of the district with the northern arm ending near Teal Lake and the southern arm on the south side of Goose Lake. The northern very narrow arm extends from Mt. Mesnard, in section 35, T. 48 N., R. 25 W., about three miles south of the city of Marquette nearly due west for a distance of about 10 miles. The southern arm, due to transverse folding, is much wider and very irregular in outline and extends southwest to the foot of Wewe hills, a distance of over seven miles. The exposures are usually in the form of sharp and abrupt cliffs, cut by ravines and drift filled valleys, and are abundant in the vicinity of Kona Hills in sections 15, 17, 23, T. 47 N., R. 25 W.

Character. The formation is cherty dolomite containing interstratified layers of slate, graywacke, and quartzite, and gradational phases between the various mechanical sediments and the pure dolomite. The dolomite beds vary in thickness from a few inches to many feet thick and locally form only a third to a half of the formation. The purest of the dolomite beds contain thin cherty layers mingled with mechanical sediments. The texture of the dolomite varies from very dense grained to very coarsely crystalline, approaching marble. The color varies from nearly pure white to pink and red or dark brown. The layers of siliceous and argillaceous material also show a wide variation in color, hence the rock ledges differ greatly in appearance.

The dolomite has been greatly fractured and brecciated, though in most cases the fracturing is so minute as not to be recognizable except under the microscope. The brecciation in the layers of quartz, slate, and graywacke is much coarser. After brecciation the fragments were cemented together by coarsely crystalline quartz or dolomite, or both together. The bands and fragments of siliceous material stand out as ridges or nodules on weathered surfaces giving a very rough and jagged appearance.

Composition. The purer phases of the rock are heavily magnesian, generally approaching normal dolomite. The abundance of siliceous, argillaceous, and ferruginous impurities renders it of little value except for road metal, ballast, and rough building stone.

Trap rock, owing to its superior hardness, toughness, and high cementing value makes the best known road material. Because of

*C. R. VanHise and C. K. Leith. The Marquette Iron District, Mon. LII, U. S. Geol. Surv. 1911, p. 258; also C. R. VanHise, The Marquette Iron Bearing District, Mon. XXVIII, U. S. Geol. Surv. 1897, p. 240-256.

its fire resisting qualities, it is also much superior to limestone as an aggregate in concrete mixtures. Marquette county has an abundance of trap rock, hence the beds of dolomite probably will never be of much economic value as a source of crushed stone.

Numerous projects have been started for developing the marble-like phases of the Kona and Randville dolomites, but thus far nothing has come of them. The vari-colored crystalline portions when polished are said to be very beautiful, but it is probable that the impurities would result in a large amount of waste in quarrying. Moreover, many of the layers of argillaceous and siliceous material are schistose or slaty, thus tending to produce parting planes. For these reasons it is doubtful that the pre-Cambrian dolomites are susceptible of development for marble or building stone.

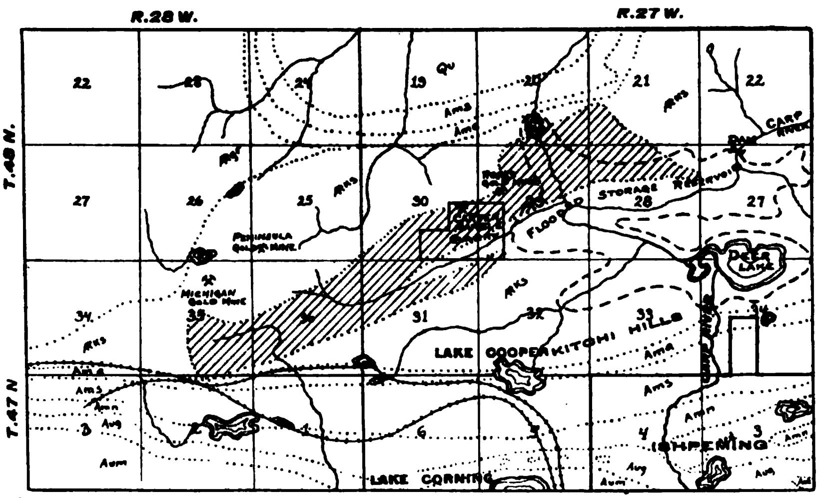


Figure 10. Map showing the distribution of the peridotites northwest of Ishpeming, Marquette county. (After Van Hise, Bayley and Smyth, Monograph 28, U. S. Geological Survey).

Verde antique marble. There are, however, in Marquette county certain peridotite rocks,* composed chiefly of olivine, now largely altered to serpentine and dolomite, to which the name *verde antique* marble has been applied. Northwest of Ishpeming a belt of altered peridotite (fig. 10) about 4½ miles in length extends from the southern part of sec. 21, T. 48 N., R. 27 W., southwest into the southeastern part of sec. 35, T. 48 N., R. 28 W. There are a number of separate exposures, the larger ones being from 1 to 3 miles long.

In some places the rock is almost wholly dolomite, in others it is a calcareous or dolomitic serpentine. The serpentine phase predominates.

*C. R. VanHise. The Marquette Iron Bearing District, Mon. XXVIII, U. S. Geol. Surv. 1897, pp. 183-186.

The dolomite generally occurs as veins cutting the serpentine and in ill-defined bands bordering cracks and joint planes. The serpentine varies in color from light to dark green with shades of olive but the dolomite is generally white. The rock takes a high polish and the intricate veining of dolomite produces very beautiful effects.

The rock is said to be very massive and the numerous cliffs and knob-like exposures afford very favorable quarrying conditions. The Michigan Verde Antique Company, Ishpeming, Michigan, is opening a quarry in sec. 30, T. 48 N., R. 27 W., about five miles northwest of Ishpeming. Polished slabs of stone from this quarry are beautifully veined and colored, equal or superior in polish or coloration to much of the *verde antique marble* now on the market.

Analyses Nos. 15 to 17, made by Whitney* in 1859, are partial analyses of serpentine from Presque Isle and No. 18 of peridotite† from the vicinity of Opin Lake, 1220 paces north, 500 paces west of the southeast corner, section 27, T. 48 N., R. 27 W.

Analyses of Serpentine and Peridotite.

	No. 15.	No. 16.	No. 17.	No. 18.
SiO_2	36.95	37.25		39.37
Al_2O_3				4.47
Fe_2O_3	16.50	6.75	12.90	4.96
FeO		14.14	19.52	9.13
CaO				3.70
MgO	33.07	28.67	14.82	26.53
MnO				.12
TiO_2				.66
Cr_2O_3				.68
NiO				.21
SrO				trace
BaO				trace
K_2O				.26
Na_2O	.97	1.16		.50
H_2O, below 110°	10.40	10.89		.87
H_2O, above 110°				7.08
P_2O_5				.17
CO_2				1.23

PALEOZOIC LIMESTONES.

Alger County.

Distribution and Character. The Beekmantown (Calciferous) sandstone forms a sinuous belt across the central portion of Alger county from the southwest to the northeast. It is well exposed in the vicinity of Chatham, Alger county, especially along the upper course of Au Train River. It is also exposed south of Munising. Analyses Nos.

*J. D. Whitney, Notice of new localities and interesting varieties of minerals in the Lake Superior region, Am. Jour. Sci., Vol. XXVIII, 1859, p. 18.

†C. R. VanHise. The Marquette Iron Bearing District, Mon. XXVIII, U. S. Geol. Surv. 1897, p. 186.

19 to 23 show that locally it is a very sandy dolomite. In places the sand content is low and quite possibly in some places it is sufficiently pure for use as a basic lining of furnaces. The stone is sufficiently massive and durable for use as building stone, but its distance from markets and the abundance of other stone equally suitable for building purposes nearer good markets make it of no present importance for such purposes.

Alpena County.

Distribution. The Traverse* formation (figs. 9 and 11) occupies the northeastern half of Alpena county and the Antrim shale, the slightly smaller southwestern half. Rock is at or near the surface over most of the northeastern half except near the western margin. The Long Lake, or Lower Traverse series, the Alpena, or ''Middle'' limestone, and the Thunder Bay or Upper Traverse series form three roughly parallel belts extending in a general northwest-southeast direction across the eastern half of the county. The limestones and shales of the Long Lake series cross the northeastern corner from the vicinity of Misery or Little Thunder Bay into Presque Isle county and they can be definitely traced as far northwest as Rogers City and Black Lake. The Alpena series forms a belt between 4 and 5 miles wide extending from North Point, Thunder Bay peninsula, into Presque Isle county and across the central part of Presque Isle county in the vicinity of Onaway into the central portion of Cheboygan county. The Upper Traverse shales and limestones occupy the southwestern belt, apparently 6 miles or more in width, which extends from Partridge Point northwest into Presque Isle county.

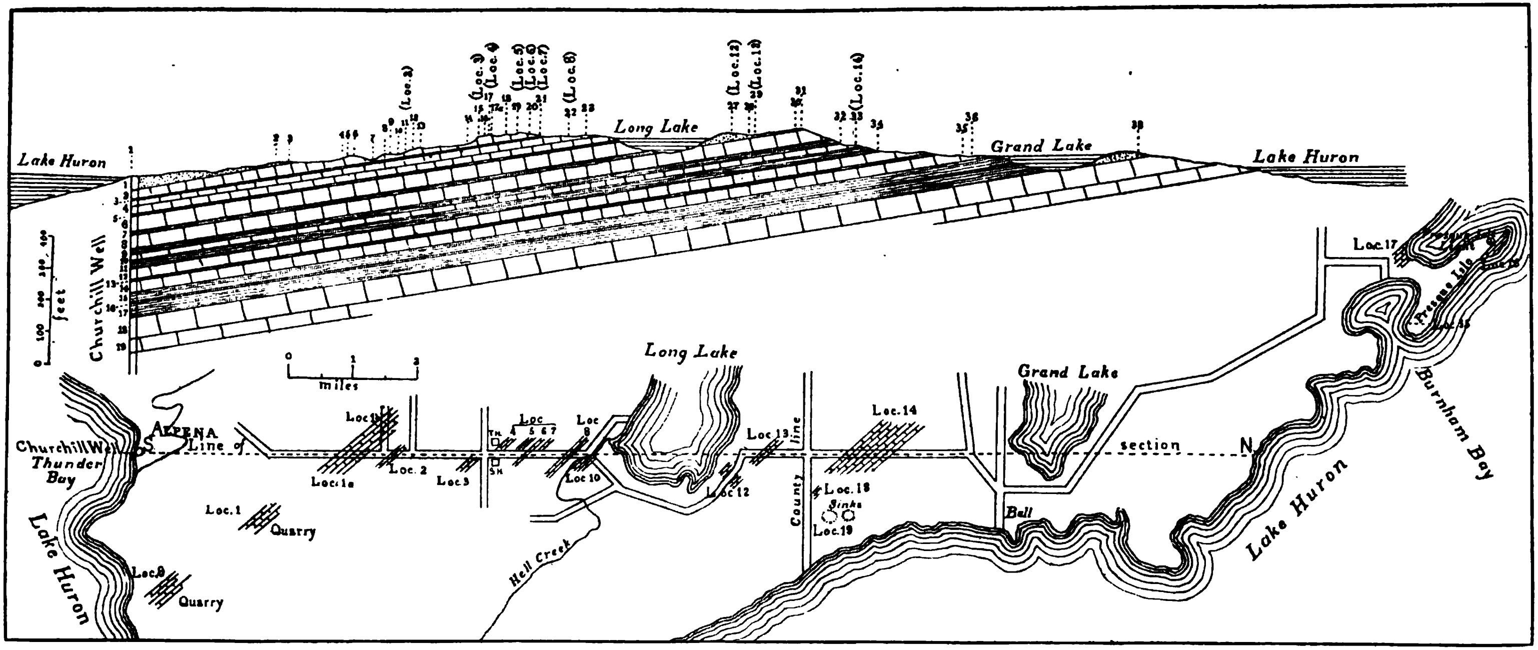
Long Lake Series. The Long Lake group consists of alternating beds of limestone and shale. Most of the limestone is more or less argillaceous, and some of it is more nearly shale than limestone.

The shale is generally very calcareous and almost every variety of rock from pure limestone to pure shale may be found. Many of the beds of limestone are also very bituminous and fossiliferous. Most of the black limestones are locally extremely fossiliferous. The most notable of these fossiliferous beds occurs at the base of the series and lies directly over the Bell shale. At Rockport (see Rockport quarry) this bed is 25 to 30 feet thick.

Some of the limestones are very massive and resistant to erosion and give rise to roughly parallel lines of prominent escarpments facing northeast with long gentle slopes on the southwest.

The shales and more argillaceous and thin bedded limestones occupy the valleys between the lines of escarpments. The bottoms of some of

*See previous chapter for general description of the formation.



Bed 1 - sand and gravel.
Bed 3 - thin shale bed.
Bed 5 - " " "
Bed 13 - " " "
Bed 16 - thin limestone beds.

Figure 11. Geologic section from Alpena, Alpena county, north to Lake Huron. (After A. W. Grabau).

the valleys are occupied by lakes and swamps. The numerous escarpments afford very favorable opportunities for quarrying but unfortunately the argillaceous character of much of the limestone and the occurrence of seams and beds of shale make most of the beds of little economic value. It is possible, however, that some of the argillaceous limestones may be found suitable for the manufacture of natural cement.

The Alpena Portland Cement Co. obtained their supply of shale from an exposure in section 18, T. 32 N., R. 9 E. Several shale beds from a few inches to 18 feet thick and considerable argillaceous limestone was struck in test holes in the western part of sections 20, 30, 31, and 32 of the same township. Shale and argillaceous limestone was also encountered in test holes just across the line in southeastern Presque Isle County. Very argillaceous limestones are exposed at Beck's Mill at the falls of Hell Creek in section 23, T. 32 N., R. 8 E., and along the highways to the south and east of Long Lake, on Thunder Bay Island, at El Cajon Beach (sec. 10, T. 31 N., R. 9 E.), and Misery or Little Thunder Bay, and at many other places. It must not be inferred, however, that none of the exposures contain pure limestone. On the contrary in many of the exposures there are massive beds of high calcium limestone under very favorable conditions for quarrying, but the relatively thin sections of marketable limestone in most of these exposures do not permit of quarrying operations on a large scale. There are numerous deposits of pure limestone sufficiently large to supply the needs of lime burners or the local demands for crushed stone, etc. The day of the small operator and crude methods, however, is past and it is only under favorable local conditions that small operators can compete with the many limestone products companies now operating on a large scale with the most efficient methods and equipment.

Quarries and Localities.

Rockport. At Rockport, the Great Lakes Stone & Lime Company have recently opened a large quarry in the thick, massive and extremely fossiliferous bed at the base of the Long Lake series. The bed is from 25 to 30 feet or even more thick and forms an almost continuous bluff extending from the north line of section 6, T. 32 N., R. 9 E., southeast along the shore of Lake Huron for more than a mile. The bed rests directly on the soft blue Bell shale, the bench between the lake and the bluff being formed largely of the shale. From the top of the bluff the surface rises gently to the west for about a third of a mile where there is a second terrace. Farther inland there are other terraces.

These upper terraces are composed of higher lying beds of the Long Lake series and undoubtedly include beds of shale and argillaceous limestone.

The Rockport Limestone is essentially stromatopora, coral, etc., with a matrix of dark or black crystalline and very bituminous limestone. The stone contains from about 94 to nearly 98 per cent of calcium carbonate. Analyses Nos. 24 to 29 show the general character of the stone. It is said to be especially well adapted for flux. Owing to its very bituminous character, however, it does not burn well. The bituminous pieces are apt to have a dark carbonaceous core but the white masses of stromatopora, coral, etc., burn well and make excellent chemical lime.

A natural escarpment parallel to the lake shore and relatively thin overburden afford exceptional advantages for development. Due to the presence of a transverse drift filled ravine the quarry face has been developed only along the northern portion of the bluff. Later it is planned to extend the workings to the southeast beyond the ravine. A harbor has been dredged, docks erected, and a modern crushing plant has just been completed with a rated capacity of over 1000 tons per hour.

The floor of the quarry is formed of the soft blue shales of the Bell member. At the top of this there is a thin, very fossiliferous bed. Below this the shale is apparently non-fossiliferous and homogeneous and probably will be found suitable for various brick and tile products. With the progress of quarrying operations a large supply of shale will become available under exceptionally favorable quarrying conditions.

El Cajon Beach. At El Cajon Beach (sec. 10, T. 37 N., R. 9 E.) dark argillaceous limestones form a prominent flat topped bluff along the Lake Huron shore 40 to 50 feet above the water. There is practically no overburden on the top of the bluff, which faces a beautiful bay about a half mile wide. The bay is almost land locked by a barrier beach. About 15 years ago the El Cajon Portland Cement Company planned to build a plant for the manufacture of cement from the argillaceous limestones. A quarry was opened and hydraulic lime or cement was burned for making the foundations of a large plant. The company failed and the project was abandoned. The foundations are now crumbling to decay.

The favorable quarrying conditions here and a good harbor afford exceptional advantages for development.

The lower beds are covered with talus from the bluff. The visible beds are dark and argillaceous, containing over 6 per cent of alumina and iron and nearly 33 per cent of silica. The magnesia, however, is

low. Analysis No. 42 was made from a composite sample and shows the argillaceous character of the beds.

Misery (Little Thunder) Bay. At the head of this inlet there is a large sink hole known as the "bottomless hole," from which strong springs arise. The western wall of this sink is a vertical cliff composed of thin bedded limestones separated by shale partings. Large masses are continually breaking off and falling into the bay. At present there is a large crevice from a few feet to 10 feet wide extending roughly parallel to and at a short distance from the shore for several hundred yards. In this crevice alternating beds of pure limestone and argillaceous limestone, typical of the Long Lake series, are exposed. Were the stone of commercial grade the favorable quarrying conditions and the deep natural harbor would invite development.

Exposures of the Long Lake series are very numerous throughout much of the belt and are characteristically shaly and argillaceous. Analysis 90 is of a compact gray limestone* near the top of the series, exposed on the Long Lake road along the east line of sec. 27, T. 31 N., R. 8 E.

So far as known the Rockport limestone at the base of the series is the thickest bed, free from shale and argillaceous matter. It is probable that exposures of this bed in Alpena county are confined to the vicinity of Rockport. Northwest in Presque Isle county the bed apparently comes to the surface some distance west of Grand Lake.

Alpena Limestone. The Alpena limestone is a group of very massively bedded gray and buff crystalline high calcium strata characterized in the Alpena region by reefs of white coral. The group includes some interbedded shale and shaly limestone, locally very cherty and bituminous. Some of the upper beds contain more or less magnesia and locally the reef limestone contains magnesian or dolomite "chimneys."

Michigan Alkali Company quarry. The Alpena limestone is best exposed in the vicinity of Alpena, particularly in the large quarry (Pl. II A) of the Michigan Alkali Company in the eastern part of the city. This quarry consists of a roughly circular opening, the area of which is said to be between 60 and 70 acres. Quarrying is conducted on two levels. The face on the upper level varies from about 40 to nearly 50 feet. The lower level was just being developed in 1914 and the working face was then only about 30 feet and wholly below lake level. A sump, however, had been excavated below the floor of the

*A. W. Grabau. Stratigraphy of the Traverse formation, Ann. Rept. 1901, Mich. Geol. Surv., p. 179.

lower quarry so that the height of the exposure was between 80 and 90 feet. The great size and depth of the quarry affords exceptional opportunity for study of the reefs and intervening beds. The reefs are mounds and ridges of very white coral limestone. Some of the mounds are more or less connected, others are isolated. More commonly they are united and form more or less continuous and anastomosing system of ridges. The mounds and ridges can be traced for considerable distances in the vicinity of Alpena.

The beds dip away from the reefs at rather steep angles but at short distances they flatten out and become nearly horizontal. Many of the beds are continuous from one reef to the next. The fossil materials of the reefs interfinger with the beds and locally masses of reef material occur between the beds at some distance from the parent reef.

The following is a section of the southeastern side of the upper quarry midway between two coral reefs and represents only the massive crystalline and less fossiliferous beds:

Section in Upper Quarry.

No. of Bed.		Thickness, ft.	Depth, ft.
1.	Hard buff crystalline limestone...... $CaCO_3$ 90.43% $MgCO_3$ 8.31% Anal. No. 30.	4+	4+
2.	Grayish buff crystalline limestone. Similar to No. 1. $CaCO_3$ 90.43% $MgCO_3$ 8.31% Anal. No. 30.	2	6
3.	Hard grayish buff crystalline limestone with some bituminous streaks...... $CaCO_3$ 94.54% $MgCO_3$ 2.61 Anal. No. 31.	9	15
4.	Shaly and cherty limestone......	2	17
5.	Dark gray crystalline limestone with bituminous streaks. $CaCO_3$ 92.38% SiO_2 4.03 Anal. No. 32.	4	21
6.	Shaly, fossiliferous, and cherty limestone. Much soft shale......	3+	24
7.	Light buff crystalline limestone...... $CaCO_3$ 95.58% Anal. No. 33.	3	27
8.	Dark gray crystalline limestone with shaly streaks and chert nodules......	4	31
9.	Buff crystalline limestone......	2	33
10.	Grayish buff crystalline limestone similar to No. 2...... $CaCO_3$ 94.78% Anal. No. 34.	6+	39+

The following is a continuation of the section in the lower quarry. There is a gap between the two sections of 6 to 10 feet.

No. of Bed.		Thickness, ft.	Depth, ft.
	Missing	10+	49
11.	Dark crystalline and crinoidal limestone	3	52
12.	Dark bituminous limestone with interbedded coral masses	7	59
13.	Dark gray massive limestone with scattered heads of coral	8	67
14.	Crystalline limestone, with stylolitic structure. $CaCO_3$ 96.40% Anal. No. 35.	5	72
15.	Dark fine grained bituminous limestone	4	76
16.	Argillaceous (?) limestone or limestone of inferior quality	....	....

The reefs vary from about 50 to nearly 100 feet wide, though measured from the extremities of some of the interfingering masses of coral which extend outward from the reefs the width is much greater.

The reef rock is generally very pure, in places, containing over 99 per cent of calcium carbonate. (Anal. No. 49). Locally there are heavily magnesian areas in the reefs, called magnesian or dolomite "chimneys." Generally the stone in such areas is more or less stained yellow by iron and is extremely porous or sponge-like. Owing to its extreme porosity the magnesian stone is in great demand by paper manufacturers using the sulphite method.

The composition of the beds between the reefs varies vertically from bed to bed and horizontally in the individual beds. The upper beds in the Michigan Alkali quarry contain considerable percentages of magnesia (Anal. No. 30) and some of the middle ones are very siliceous or argillaceous. The interbedded shale and argillaceous limestone ordinarily would result in much waste material but this, together with the "fines" or limestone screenings is utilized for the manufacture of Portland cement by the Huron Portland Cement Company, whose plant is located on Thunder Bay a short distance from the quarry. Excepting the upper beds, the Alpena limestone is dominantly high calcium. The magnesian stone causes little trouble because in the process of quarrying it is mixed with so much of the exceptionally high calcium stone that its effect is barely noticeable in the quarry product.

Analyses Nos. 30 to 34 show the general character of the crystalline limestones on the southeast side of the upper quarry and No. 35 the limestone in the lower quarry. No analyses were made of the beds of shale and argillaceous and cherty limestone. Analyses Nos. 36 to 41 are of hand specimens from different beds in the quarry.

A large part of the select stone is shipped by boat to Wyandotte and Ford City for the manufacture of soda ash, bleach, caustic, etc. A

large amount of stone, including the "fines" or argillaceous screenings is also used in the manufacture of Portland cement. The remainder of the quarry product is disposed of for a variety of purposes.

Alpena Portland Cement quarry. The abandoned plant and quarries of the Alpena Portland Cement Company are near the shore of Thunder Bay about three-fourths of a mile east of the quarry of the Michigan Alkali Company, but at a lower level. On the occasion of the writer's visit the quarries were full of water and only the upper beds were accessible. Probably these beds are to be correlated with those in the lower quarry of the Michigan Alkali Company. The south face of the quarry is composed of reef limestone and other beds dipping away from it.

The prevailingly high calcium character of the stone is shown by analyses Nos. 43 to 62.

Richard Collins quarry. This is a small quarry operated for lime burning about two miles north of the Michigan Alkali Company's quarry. The opening is in dense, light gray, fragmental reef-limestone, in every way similar to the fragmental portions of reefs in or about the quarries of the Alpena Portland Cement Company and the Michigan Alkali Company. The high quality of the stone is indicated by analyses Nos. 63 to 65.

Owen Fox's quarry. This quarry is located about two miles north and slightly west of the Michigan Alkali Company quarry. The general dip* of the strata is 4 degrees to the south. In the eastern end the dip increases from 8 to 18 degrees, the steepest dip being in the easternmost portion where the abundance of corals indicate the neighborhood of a reef. On the southwest these beds are overlain by dark shaly limestones and bituminous shales with a rich coral and brachiopod fauna. Analyses Nos. 66 and 69 show the great purity of the unaltered Acervularia and Stromatopora limestone. The upper beds contain only 1.33 per cent of magnesia, but the lower ones 4.20 per cent.

*A. W. Grabau, The Stratigraphy of the Traverse Formation, Ann. Rept. Mich. Geol. Surv. for 1901, p. 176.

Analysis of Drill Core, Hole No. 38, Alpena.

On the East ½ of section 12, T. 31 N., R. 8 E.

B. H. Taylor, Carnegie Steel Co., Pittsburgh, Pa., 1909.

No. Anal.	Depth.	SiO_2.	Al_2O_3.	Fe.	$CaCO_3$.	CaO.	$MgCO_3$.	MgO.	Sul.	Phos.
93	6-11 ft..	5.72	2.97	.36	87.6	49.11	**2.40*	1.15	.193	.019
94	11-16 ft..	3.88	1.96	.56	89.4	50.63	*2.26*	1.08	.187	.018
95	16-21 ft..	2.90	1.45	.30	93.0	52.11	*1.96*	.94	.123	.017
96	21-26 ft..	3.72	2.30	.32	90.8	50.94	*2.11*	1.01	.183	.019
97	26-31 ft..	1.80	1.45	.22	93.6	52.58	*1.80*	.86	.217	.016
98	31-36 ft..	.50	.54	.46	90.0	50.51	*7.82*	3.74	.143	.005
99	36-41 ft..	.48	.65	.40	92.0	51.55	*6.02*	2.88	.207	.006
100	41-46 ft..	1.28	1.07	.32	94.4	52.95	*2.24*	1.07	.250	.019
101	46-51 ft..	6.10	3.54	.45	87.6	49.04	*2.21*	1.06	.385	.041
102	51-56 ft..	1.96	1.62	.38	93.4	52.34	*3.18*	1.52	.188	.020
103	56-61 ft..	6.16	3.44	.57	85.7	48.13	*3.80*	1.82	.484	.033
104	61-66 ft..	4.42	4.37	.36	86.6	48.56	*1.98*	.95	.876	.030
105	66-71 ft..	2.36	2.81	.35	90.0	50.33	*1.88*	.90	.320	.010
106	71-76 ft..	.58	.90	.24	96.0	53.86	*1.96*	.94	.259	.009
107	76-81 ft..	.34	.50	.23	97.0	54.41	*1.80*	.86	.155	.007
	Average Anal....	2.81	1.98	.37	91.2	51.14	....	1.37	.278	.018
108	81-86 ft..	1.58	.78	.66	91.8	51.48	*4.70*	2.25	.242	.006
109	86-91 ft..	3.18	1.91	.57	90.3	50.51	*3.43*	1.64	.242	.010
110	91-96 ft..	12.78	7.91	.72	73.7	41.30	*3.01*	1.44	.488	.021
111	96-98½ ft..	12.28	7.39	.74	74.8	41.91	*3.43*	1.64	.426	.018

*Figures in italics are calculated from original analyses.

Analysis of Drill Core, Hole No. 1, Alpena.

N. ½ of sec. 13, T. 31 N., R. 8 E.

B. H. Taylor, Carnegie Steel Co., Pittsburgh, Pa., 1909.

No. Anal.	Depth.	SiO_2.	Al_2O_3.	Fe.	$CaCO_3$.	CaO.	$MgCO_3$.	MgO.	Sul.	Phos.
112	2- 7 ft..	.42	.46	.42	96.5	54.05	1.84	.88	.015	.020
113	7- 12 ft..	1.00	.46	.66	96.2	53.93	1.50	.72	.075	.022
114	12- 17 ft..	2.94	1.49	.44	93.2	52.24	1.13	.54	.091	.013
115	17- 22 ft..	2.68	2.27	.38	93.5	52.47	.84	.40	.067	.014
116	22- 27 ft..	2.12	1.84	.38	93.5	52.47	1.96	.94	.072	.015
117	27- 32 ft..	.68	.52	.32	95.7	53.57	1.90	.91	.042	.018
118	32- 37 ft..	.86	.49	.34	95.7	53.57	1.96	.94	.071	.019
119	37- 42 ft..	1.66	1.37	.36	94.1	52.78	1.73	.83	.097	.018
120	42- 47 ft..	3.42	2.07	.30	91.3	51.26	1.65	.79	.150	.017
121	47- 52 ft..	3.42	2.55	.36	90.8	50.95	1.50	.72	.150	.020
122	52- 57 ft..	2.36	1.58	.24	93.5	52.47	1.50	.72	.110	.017
123	57- 62 ft..	3.12	1.81	.34	93.8	52.49	1.50	.72	.158	.015
124	62- 67 ft..	.84	.79	.26	94.6	53.00	1.50	.72	.150	.020
125	67- 72 ft..	.76	.21	.40	94.4	52.96	3.62	1.73	.116	.012
126	72- 77 ft..	.94	.58	.34	96.8	54.24	1.50	.72	.116	.008
127	77- 82 ft..	2.72	1.17	.34	96.8	54.24	1.96	.94	.166	.005
128	82- 87 ft..	3.74	2.28	.32	91.2	51.03	1.50	.72	.232	.040
129	87- 92 ft..	2.00	2.29	.36	93.5	52.36	1.50	.72	.197	.022
130	92- 97 ft..	1.98	1.45	.44	92.0	51.51	2.88	1.38	.280	.025
131	97-102 ft..	2.28	1.99	.40	93.4	52.29	1.69	.81	.333	.015
132	102-107 ft..	.44	.04	.28	97.6	54.72	1.61	.77	.100	.006
133	107-112 ft..	.36	.19	.26	96.0	54.36	1.61	.77	.167	.005
134	112-117 ft..	.68	.22	.24	96.4	54.00	1.71	.82	.146	.005
135	117-122 ft..	1.50	1.01	.36	94.0	52.60	1.96	.94	.247	.008
137	122-125 ft..	.54	.21	.22	97.6	54.72	1.50	.72	.107	.005
	Average	1.74	1.17	.35	94.4	52.95	....	.83	.138	.015
138	117-125 ft. Cuttings.	1.54	1.96	.52	....	52.36	....	.72	.240	.016

Gilbert Olson's quarry. This is a very small opening in S. E. ¼ S. W. ¼ sec. 18, T. 31 N., R. 9 E., formerly operated for lime burning. The stone is a light gray, dense grained, fragmental reef limestone similar to that in the Collins and Alpena Portland Cement quarries. The exposure forms a low mound adjacent to a swamp. Across the road the surface is much higher and limestone is exposed at many places in the S. W. ¼ sec. 18.

Other localities. The Alpena limestone is at the surface or under very light cover over large areas north and northeast of Alpena in sections 6, 7, and 18, T. 31 N., R. 9 E., and sections 1, 2, 11, and 12, T. 31 N., R. 8 E. Analyses Nos. 70 to 75 are from various exposures in this vicinity, the exact location of which are not known. Analyses 93 to 138 are of cores from two test holes in sections 12 and 13, T. 31 N., R. 8 E. In hole No. 1, which is in the vicinity of the Michigan Alkali quarry the limestone, to the depth of 125 feet, averages 94.4 per cent

calcium carbonate. In hole No. 38 many of the beds are siliceous, argillaceous and comparatively low in calcium carbonate, though the magnesia exceeds 2 per cent in but three analyses. From 91 to 98 feet the silica and alumina form nearly 20 per cent of the rock.

The high average purity of the rock in the first hole may be due to its nearness to reef limestone and the relative impurity of the stone in the other to its greater distance from reef limestone. The bottom beds in hole No. 38 apparently belong to the Long Lake series. The depth of the pure limestone in hole No. 1 indicates that the Alpena stone is thicker than apparent in the Michigan Alkali quarry. It is obvious, however, that in the vicinity of Alpena, due to the great horizontal variation in the composition of many of the beds, drill holes do not always furnish conclusive evidence of the precise character of the limestone beds. Exposures are abundant north and northwest of Alpena along the elevated tract to the Presque Isle County line. Two miles north of Alpena on the Long Lake road near the southwest corner of sec. 35, T. 31 N., R. 8 E., there is an exposure of a highly fossiliferous limestone consisting chiefly of stems and joints of crinoids and of various bryozoa. Analysis No. 89 shows that it contains considerable silica. One mile north in a well drilled by E. S. Beal in the S. E. corner section 26, T. 31 N., R. 8 E., over 54 feet of solid limestone was penetrated.

Reef limestone is exposed in the N. E. corner of section 4, T. 31 N., R. 8 E., but, one-half mile east, light blue argillaceous limestone was encountered in a shallow well on the Chas. Allen farm near the S. ¼ post of sec. 33, T. 32 N., R. 8 E. On the Leon Mainville farm S ½ S. E. ¼ sec. 29, T. 32 N., R. 8 E., reef limestone is exposed over a large area and according to Mr. E. S. Beal, a man of wide experience in drilling, 154 feet of good limestone was penetrated in a well across the road near the S. W. corner section 28, the hole ending in black shale. The Alpena series is well exposed in numerous sinks in the vicinity of Bolton. The following section is exposed in a sink in the N. W. corner of section 14, T. 32 N., R. 7 E.:

	Feet.
Crinoidal limestone	1
Massive gray limestone	2
Acervularia limestone	4
Dark crystalline limestone	4
Very shaly and bituminous limestone	1
Gray crystalline limestone	2.5
Shale seam	0.5
Gray crystalline limestone	3
Talus	50

A similar series of beds is exposed in another sink about 120 rods east and slightly south. Mr. E. S. Beal drilled a well with a core drill 137 feet in depth near the northwest corner of section 16, T. 32 N., R.

8 E. Four feet of black shale was struck at 54 feet, all the rest of the rock being limestone.

The sections exposed in the sinks and penetrated in the wells indicate that the Alpena limestone series is thicker to the northwest or that the upper portion of the Long Lake series becomes less shaly west of Long Lake. No analyses were made of the cores from the wells, but if the stone is low in magnesia there is a large reserve of high grade limestone in the northern portions of Alpena and Maple Ridge townships.

M. J. Griffin quarries. These quarries, now abandoned, are about one and a half miles northwest of Bolton, near the Detroit and Mackinac railroad in the S. E. ¼ section 5, T. 32 N., R. 7 E. The quarries are small and only about 8 feet of stone is exposed. Near the top the beds are extremely fossiliferous. The top bed is composed of a mass of crinoid stems. At the bottom of this bed there is a 6 inch stratum composed almost entirely of brachiopods. Near the bottom of the section the beds are dark and contain argillaceous and bituminous material. The stone is very pure and well suited for chemical and fluxing purposes as indicated by analyses Nos. 76 to 88.

Numerous exposures of the Alpena series occur in the vicinity of Bolton on the side of the valley of Thunder Bay river. Reef limestone occurs in the N. E. ¼ section 20, T. 32 N., R. 7 E., a mile and a half south of the station. This evidently belongs to the upper portion of the series since the shaly Upper Traverse series occupy the valley of the Thunder Bay river to the southwest.

Summary. The Alpena series in Alpena County is essentially high calcium limestone containing reefs of great purity and beds of massive crystalline gray to buff limestone with some interbedded shale and argillaceous and cherty limestone. The elevated tract extending from Thunder Bay peninsula northwest into Presque Isle County is underlain chiefly by the Alpena series and contains an enormous reserve of easily accessible high calcium limestone under very favorable quarrying conditions. The inland situation, however, of most of the deposits is a factor unfavorable to their immediate development. The extensive beds of high calcium limestone in the vicinity of Alpena located near cheap water transportation are sufficient to last for a great many years.

*Thunder Bay or Upper Traverse Series.** The Upper Traverse series is not so well exposed as the middle and lower series. It consists of shale and limestone, much of the latter very argillaceous.

*A. W. Grabau. Stratigraphy of the Fraverse Formation. Ann. Rept. Mich. Geol. Series for 1901, p. 192.

Quarries and localities.

Dock Street, Alpena. A bed of clay about 6 feet in depth occurs in a test well on Dock street, Alpena, overlying the Alpena limestone. Above the clay is a bed of limestone only a few inches thick.

Fletcher Dam. Limestone is exposed at many places along Thunder Bay river, especially along the upper branches. At Fletcher Dam, section 7, T. 31 N., R. 8 E., formerly the location of Broadwells sawmill and dam, reef limestone occurs in the bed of the river. This is now concealed by the dam. Below the dam 6 feet of limestone and calcareous shale are exposed. Analysis No. 138 of this so called "hydraulic limestone" was made by N. H. Winchell about 1870. According to Winchell's unpublished field notes there are numerous exposures chiefly in sinks and cracks in T. 32 N., Rs. 6 and 7 E. In section 2, T. 31 N., R. 7 E. hydraulic cement was burned by a man named Trowbridge. The Boom Company's dam on Thunder Bay river in section 2, T. 31 N., R. 7 E., was formerly the site of Trowbridge's mill. A cliff of shale 15 feet in height occurs along the east bank. The lower part is very calcareous. Above the shale there is about a foot of subcrystalline limestone, apparently identical with the thin limestone above the Dock street clay in Alpena. Below the dam on the right bank of the river 6 feet of very calcareous shale is exposed.

Warner brick yard. Calcareous shales with thin bands of argillaceous limestone are exposed at Warner's old brick yard in the southwestern part of Alpena. The following analysis shows the calcareous nature of the lower blue portion of the exposures:

**Analysis Warner's Brick Yard Clay.*

No. Anal.	SiO_2.	Fe_2O_3.	Al_2O_3.	$CaCO_3$.	CaO.	$MgCO_3$.	MgO.	CO_2, organ., Alk., and loss.
140........	54.46	4.66	17.26	*11.79**	6.60	*5.92**	2.82	14.20

*Calculated from original analysis.

Stony Point. A cliff of limestone and shale 12 feet in height is exposed at this place. The upper 4 or 5 feet is composed of limestone with shaly partings and the lower portion of shale with thin bedded calcareous layers. The top bed of the Upper Traverse series is a brownish granular dolomite.

Summary. The foregoing data indicates that the Upper Traverse series is too shaly and argillaceous to be of much commercial importance

as a source of limestone. It is possible, however, that locally the argillaceous limestones and shales may be adapted for making natural cement.

Arenac County.

Distribution. The Grand Rapids series occupies the northeastern half of the county. The Lower Grand Rapids, or Michigan series, underlies that portion of the county north of a line drawn from the mouth of Au Gres river west-northwest to the point where the river intersects the north county line. The Upper Grand Rapids or Bay Port (Maxville) forms a belt from about 2 to 4 miles wide extending from Point Au Gres on Saginaw Bay to the northwest corner of the county. The western half of the county is heavily drift covered, hence exposures of limestone are confined to the eastern portion.

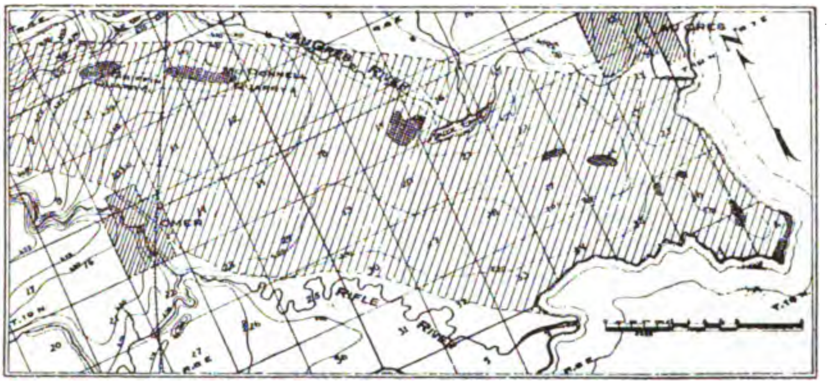


Figure 12. Map showing the distribution and the chief areas of exposures of the Bayport limestone in Arenac county. Black triangles indicate quarries.

The principal exposures of the Bayport limestone are along a low broad ridge (fig. 12) extending from Point Au Gres northwest into the southeast portion of section 34, T. 20 N., R. 5 E. Exposures of the Michigan series are almost entirely confined to a broad low ridge in Ts. 19 and 20 N., R. 20 E., lying between Lake Huron and Au Gres River and extending south-southwest roughly parallel to the lake shore.

The Bayport formation* in Arenac County is composed of limestone, generally very sandy or cherty, thin bedded, and full of fossils, and hard gray or white sandstone. The thickness of the member at Omer is apparently about 45 feet and the high calcium layers form only a small fraction of this.

*W. M. Gregory. Geology of Arenac County. Pub. 11, Geol. Ser. 8, Mich. Geol. and Biol. Surv., 1911, pp. 47-52.

Quarries and Localities.

Pt. Au Gres. An 8 foot bluff of limestone extends along the lake shore at Pt. Au Gres for a half mile. The upper 5 feet is sandy and contains traces of green shale and the lower 3 feet is light gray, very brittle limestone with nodules of chert and fossils. The stone was formerly quarried for building stone and it has proven very resistant to weathering. To the northwest of Point Au Gres limestone is exposed under light overburden in several places in sections 27, 28, 35, and 36, T. 19 N., R. 6 E. In section 27, as shown by the schoolhouse well, the limestone is only 5 inches thick and is underlain by 3 to 4 feet of brown sandstone and 7 feet of dark grayish limestone with sandy streaks.

Duck Lake quarries. Limestone is a'so reported to occur south of Duck Lake and on the west side of the lake. In sections 16 and 17, T. 19 N., R. 6 E., it forms a low flat ridge in which two or three small quarries have been opened for building stone. The Omsted quarries are in the southeast corner of section 17 where there are about 8 acres of limestone under light drift cover. The quarries consist of two small openings. In the one near the road a face of about 4 feet of very cherty limestone is exposed. In the other, located some 20 rods southeast, the upper 3 feet is very cherty. This is underlain by one foot of very shaly limestone, a 4 inch layer of fossils, and an 8 inch layer of dark lithographic limestone. Analysis No. 141 shows that the stone is a siliceous dolomite. The generally sandy, cherty, and magnesian nature of the limestone in this vicinity makes it unsuitable for most purposes excepting building stone or crushed stone for road making, concrete and ballast.

McDonnell quarry. The Jas. McDonnell quarry is located in the southeast corner of section 1, T. 19 N., R. 5 E., about 3 miles northeast of Omer at the southeastern end of a ridge of limestone which extends northwest into section 2. The quarry is operated for burning hot lime. The stone is obtained from a 3 foot layer of high calcium limestone underlain by 6 inches of argillaceous sandstone. The upper bed is a very hard dense grained white to light gray limestone. It is much fractured and disturbed by glacial action and tree roots, and stained by infiltrated clayey matter.

In 1902 Thomas Burt, former owner of the quarry, made a test boring in the bottom of the quarry, penetrating the following strata:

	Feet.	Inches.
Arenaceous limestone	6	....
Sandstone	20	....
Blue limestone	100	....
Dark shale	0	2
Gypsum	10	....

The overburden consists of a thin covering of loam and clay which is removed by shovels. The stone is pried out by bars and picks, loaded by hand on cars and drawn to the top of the kiln by horses. Wood is used for fuel. The lime is of good quality and is sold chiefly for chemical purposes and to supply the local needs.

The area underlain by the high calcium stone is unknown but it appears that it extends northwest across the adjoining property of Geo. Averill. In such case the area of available high calcium stone is between 20 and 25 acres. Analyses Nos. 141 and 142 show that it contains less than 2 per cent of magnesium carbonate. The relatively high silica content of the first analysis is due largely to the infiltrated clay and sand.

M. J. Griffin quarry. This quarry is located about three-fourths of a mile northwest of the McDonnell quarry near the opposite end of the same ridge. The quarry was operated largely for supplying crushed stone for paving and road ballast, but it has been abandoned for many years. The openings cover several acres but are shallow, varying from 4 to 6 feet in depth. The following section shows the general character of the beds:

Section in M. J. Griffin quarry.

	Feet.	Inches.
1. Gray to buff thin bedded limestone with some chert or flint nodules	2	....
2. Buff gray and gray very sandy and very cherty limestone. The bed contains many nodules of chert and flint irregularly distributed and 15 to 20 per cent of fine quartz sand	3	....
3. Black or dark limestone with shaly seams	0	2 to 6
4. Gray limestone	1 +	....

Very cherty limestone is also exposed in an old quarry just across the road in section 2 where lime was formerly burned in an old set kiln.

Analysis No. 143 is of the purest stone in the quarry. The abundance of chert and sand in most of the beds and its magnesian character renders this limestone of little value except for building stone, road metal, concrete, and ballast.

Locally the chert or flint nodules are very abundant in some of the

beds in the Bayport limestone in Arenac County, and it is possible they may prove satisfactory for use in pebble mills used in grinding Portland cement clinker. Practically the entire supply of flint pebbles is imported at the present time. Flint pebbles are expensive and it is possible that where chert and flint nodules are abundant their recovery may be a source of considerable profit.

Sections 34 and 35, T. 20 N., R. 5 E. The ridge of limestone in which the McDonnell and Griffin quarries are located is interrupted in the eastern part of section 2, T. 19 N., R. 5 E., but it reappears again in the southwestern part of section 35 and southeastern part of sec. 34, T. 20 N., R. 5 E. Hard, light gray thin bedded limestone similar to that in the McDonnell quarry is reported at several places over an area of about 150 acres. Owing to the surface covering the thickness of the stone could not be determined, but according to Gregory* it is thinner than in the McDonnell quarry and is underlain by a ripple marked sandstone. According to Mr. Tyler, part owner, an analysis made by the German Sugar Co. showed an average of about 95 per cent of calcium carbonate. Analysis No. 144, from the northeast corner of section 3, T. 19 N., R. 5 E., according to W. M. Gregory, is apparently from the sections adjoining on the north. This part of section 3 is low and swampy and the ridge of limestone lies wholly in the sections on the north. Though a high calcium stone the silica is also high, which renders it unsatisfactory for the manufacture of sugar.

White Stone Point. At White Stone Point† low ledges of grayish limestone are exposed along the lake shore and extend out under the lake for a short distance. The stone is brittle, fine grained and free from sand.

In sec. 23, T. 20 N., R. 7 E., limestone is exposed over a considerable area, terminating on the north in a low cliff or steep terrace. Formerly Harmon and Crowell operated a small quarry in this deposit for lime burning. The stone contains an abundance of chert nodules and these finally caused the abandonment of the enterprise. The section exposed is as follows:

*W. M. Gregory. Geology of Arenac County. Pub. 11, Geol. Ser. 8, Mich. Geol. & Biol. Surv. 1911, p. 51.
†Loc. Cit. p. 134.

Section in Harmon and Crowell quarry.

	Feet.	Inches.
Boulder clay	6	11
Sandy limestone	....	6
Gray limestone with abundant chert nodules in upper portion 2 to 3 inches in diameter	9	....

Limestone was also obtained for burning from a small exposure in section 24 on the lake shore. The bed is only 1½ feet thick and is covered with shale.

The limestone ridges in which the above quarries were opened begin near the southeast corner of section 13, T. 20 N., R. 7 E., and extend southwest into section 23. Analysis No. 145 said to be from the top layer shows that it is a high calcium limestone.

Many of the limestone strata in T. 20 N., R. 7 E., resemble those of the Bayport, northeast of Omer, and it is possible that they belong to this formation rather than to the Michigan or gypsum bearing series. Due to the extremely flat dip (about 15 feet per mile) of the strata to the southwest in Arenac county, the Bayport limestone may exist in the northeastern part of the county as a thin capping over the higher portions of the rock ridges.

Summary. The limestone resources of Arenac County are relatively small. The beds of high calcium stone are thin and associated with sandy, cherty, or magnesian limestone and shale, hence the greater portion of the quarry products is adapted only for building stone, concrete, road making, and ballast. The beds, however, are situated in a low flat clay region of the Saginaw Valley practically without other sources of suitable material for road making, therefore they are of very considerable local importance. The rapid settlement of the fertile clay lands in the eastern part of the county and the necessity for good roads will undoubtedly cause the early development of many of the deposits. Quite probably the developments will lead to the discovery of beds of high calcium limestone which, due to the scarcity of such stone in the central and larger portion of the Southern Peninsula, will be of importance to some of the sugar, chemical, and other industries dependent upon high calcium limestone. The cherty or flinty limestone may also become valuable as a source of pebbles for use in the manufacture of Portland cement. In brief the limestone resources of Arenac County, due to their isolated position and peculiar local conditions, have an economic importance out of proportion to their relative magnitude.

Charlevoix County.

Distribution. The northwestern portion of Charlevoix county is underlain by the Traverse formation which in the Little Traverse Bay region is chiefly limestone. The strata dip to the southeast and in the southeastern part of the county are overlain by the black shales of the Antrim formation.

The principal exposures are in the vicinity of the lake shore along high terraces cut by the glacial lakes formerly occupying the basin of Lake Michigan and standing at much higher levels than the present lake. The only considerable area of easily accessible limestone is in the vicinity of Charlevoix. The other exposures are chiefly in the form of narrow benches along the lake shore.

The Traverse is composed of alternating beds of high calcium and high magnesian limestones, as in the vicinity of Petoskey (see Emmet county). The thickness and precise character of all of the different beds and their relations, however, are not well determined.

Quarries and Localities.

Charlevoix. The largest and probably the most important area of limestone in the Little Traverse Bay region occurs in sections 28, 29, 32, and 33, T. 34 N., R. 8 W., just west of the city limits of Charlevoix. The area in which limestone is exposed or under light cover totals several hundred acres. On the east, the area is cut off by a deep valley partially occupied by Pine Lake. The limestone forms a table land generally from 20 to 60 feet or more above lake level between this rock valley on the east and Lake Michigan on the west.

The strata are locally very much disturbed. The general inclination of the beds is southward but it varies greatly in amount and direction from place to place. In one place, the dip is over five degrees to the north and an eighth of a mile distant over 22 degrees to the south. The rock series includes an upper horizon of high calcium limestone with a thin shale bed, a middle thick shale bed, and a lower series of limestones, apparently high calcium in composition but with some siliceous and argillaceous beds. Due to the general southward inclination, successively lower beds are exposed in passing from south to north across the area. The strike of the beds is in a general east and west direction but this is considerably modified locally by the sharp variations in dip. The limestone area is divided into two parts. The northern or smaller one includes Pine River Point and is separated from the much larger southern part by a narrow belt underlain by the middle shale.

Charlevoix Rock Products Company quarry. The Charlevoix Rock Products Company's quarry (Pl. II B) and limekilns are located a short distance northwest of the City of Charlevoix in the SE. ¼ SE. ¼ of section 28, T. 34 N., R. 8 W. At the time of the writer's visit in 1914, Quarry No. 1, located at the plant, was an irregular opening about 400 feet in greatest diameter and about 23 feet in greatest depth. The following section was exposed in the workings:

Section in Charlevoix Rock Products Co. quarry.

		Feet.	Inches.
Surface or overburden about		1	....
Light buff, friable, and sandy appearing limestone. Top portion much fractured and disturbed	Average Anal. 97.46 per cent. $CaCO_3$	18	....
Light buff fine grained earthy limestone		1	6
Banded buff to dark gray earthy limestone		2	6
Fine grained buff limestone, the floor of the quarry		0	8 to 10
Blue shale very soft and said to be very uniform in character and composition		10	6

The beds dip gently southward. Toward the west, however, the dip of the beds locally becomes discordant and much steeper as shown in a small quarry located about a quarter of a mile west-southwest of the plant.

The beds of limestone, though rather massively bedded toward the top of the quarry, are so completely traversed by an irregular system of joint planes that the stone is won by steam shovel without blasting. The shale beneath the quarry is so soft that a 10 inch layer of limestone is left above the shale as a floor to support the tracks and steam shovel.

The beds in the quarry average over 97 per cent of calcium carbonate, less than 1.5 per cent of magnesium carbonate and 1 per cent of silica. Analysis No. 146 is fairly representative of the average composition of the stone in the quarry excluding the top broken portion. Analyses No. 147 and 148 are apparently from this quarry, although the exact location is not given.

Due to its low percentage of silica, magnesia, or other objectionable impurities the stone is especially adapted for use in the manufacturing of special steels, sugar, and paper, as well as for general fluxing and chemical purposes.

Quarry No. 2 of the Charlevoix Rock Products Company is situated about one-fourth of a mile slightly south of west from Quarry No. 1. It consists of a narrow arcuate opening about 200 feet long extending in a general east-northeasterly direction and varying from a few feet up to 9 feet in depth. In this quarry the dip of the beds is abnormal in amount and direction. At the east end the dip is 18 degrees in a

direction S. 65° E., at the center 22 degrees S. 37° E., and at the west end 5 degrees S. 15° W. On the north the floor of the quarry begins at the surface and extends downward parallel to the beds, hence the face is wholly on the south side of the opening and parallel to the strike of the beds. Due to the steep southward inclination and a gentle northward slope of the surface the edges of underlying beds are exposed on the north side of the quarry. The following section is exposed:

Section in Quarry No. 2, Charlevoix Rock Products Co.

		Thickness, feet.
	Surface	0 to 1
1.	Yellow friable, earthy and fossiliferous limestone, much weathered, $CaCO_3$, 89 per cent	3+
2.	Shale, very fossiliferous, and yellow where weathered	1+
3.	Hard gray to buff gray very crystalline limestone. $CaCO_3$, 95.94 per cent. Said to be especially adapted for sugar manufacture	4
4.	Dense white laminated limestone, the floor of the quarry	1±
5.	Extremely fossiliferous limestone. This bed is a mass of coral and stromatopora. Bed said to contain over 95 per cent of calcium carbonate	14

Bed No. 5 is said to be directly underlain by the yellow friable limestones exposed in quarry No. 1 at the plant, hence at this point there is about 45 feet of limestone above the heavy shale bed exposed in the bottom of quarry No. 1.

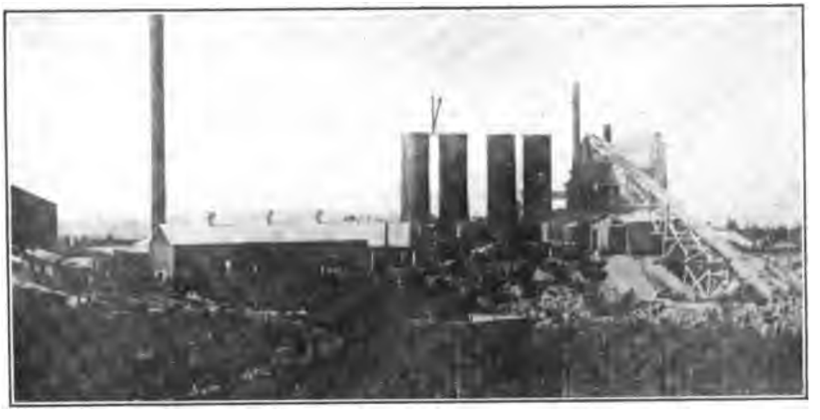
Analysis No. 149 indicates that the top bed, where fresh and unweathered is probably a high calcium limestone. The sample was taken from the exposed margin of the bed and probably farther south in the direction of the dip the stone is less weathered and of better quality. Analysis No. 150 is of a representative set of samples from the crystalline bed below the shale seam. No analyses are available showing the character of beds Nos. 4 and 5, but according to R. F. Sloan, general manager of the company, they contain over 95 per cent of calcium carbonate.

City quarry. Formerly the city of Charlevoix operated a small quarry near the northwest corner NW. ¼ NE. ¼ section 33, T. 34 N., R. 8 E., about one-eighth of a mile south of quarry No. 2 of the Charlevoix Rock Products Company. The section is apparently the same in both quarries with the exception that bed No. 3 is much thicker than in quarry No. 2. The stone was used for paving and road making.

A similar abnormal inclination of the beds occurs in this quarry. Apparently a small plunging anticline extends into the quarry from the southwest. The dip varies from 2 or 3 degrees to the northwest to about 7 degrees slightly east of north and directly toward quarry No. 1 of the Charlevoix Rock Products Company. Almost directly south the dip decreases to only 2 or 3 degrees. The dip is about 11 degrees south from quarry No. 1 and 7 degrees north from the city quarry, hence there must be a very pronounced trough or syncline in the strata

A. QUARRY AND CRUSHING PLANT OF THE MICHIGAN ALKALI COMPANY AT ALPENA, ALPENA COUNTY.

The lower quarry is shown at the right center and a portion of the new steel crushing plant at the extreme right.



B. KILNS AND CRUSHING PLANT OF THE CHARLEVOIX ROCK PRODUCTS COMPANY AT CHARLEVOIX, CHARLEVOIX COUNTY.

A portion of the quarry is faintly shown at the lower right.

between the two quarries. Since the southeastward dip in quarry No. 2 is about 20 degrees, the syncline apparently plunges to the east. South of quarry No. 1, the dip of the beds is said to be very gentle, therefore the abnormal dips noted above must flatten out quickly to the eastward.

Wolverine Lime Co. quarry. A small quarry has been opened in the S. ½ SE. ¼ sec. 29, T. 34 N., R. 8 W., in the western part of the Charlevoix limestone area. The Wolverine Lime Company owns or controls this and adjacent limestone properties and proposed to erect a modern lime plant. According to reports the enterprise did not materialize.

The quarry was about 7 feet in depth and the stone is apparently similar in character to that in the city quarry and quarry No. 2 of the Charlevoix Rock Products Company.

Analysis No. 150 is of a representative set of samples from the quarry. Analyses Nos. 152-154 were furnished by E. S. Stacks, a member of the company. These analyses show that the stone averages nearly 97 per cent calcium carbonate and less than 1 per cent of magnesium carbonate.

Lake shore. Due to the southward inclination of the beds in the Charlevoix area and the very considerable elevation of much of the area above lake level, a number of beds below the heavy shale bed of quarry No. 2 of the Charlevoix Rock Products Company are exposed at the surface northward from the quarries and along the lake shore to Pine River Point. Some of the beds are dark fine grained or lithographic in texture, others crystalline and fossiliferous. Apparently the lower series is in general low in magnesia, as indicated by analyses Nos. 155 to 159, which are supposed to be of stone from the vicinity of Pine River Point. Possibly analyses Nos. 147 and 148 are also from the lower series. The striking feature of the first set of analyses is the high silica, alumina, and iron which together average about 8 per cent. The evidence, though of doubtful nature, indicates that the character of the limestone deposits in the immediate vicinity of Pine River Point should be carefully investigated before developments are attempted.

Along the lake shore on the west, limestone is exposed at various places near water level from Pine River Point to Norwood. Close to the shore sand dunes conceal the rock. Farther inland and south of Charlevoix it is drift covered, exposures being few and small. South of Charlevoix near the west shore of Pine Lake there is an exposure of dolomite but no analyses are available. This lies above the high calcium series of the Charlevoix area but its exact position has not been determined.

From the foregoing data a generalized section of the strata exposed in the vicinity of Charlevoix is as follows:

	Feet.
Heavy magnesian limestone exposed south of the Charlevoix limestone area near Pine Lake	?
Series of high calcium limestones with a thin shale bed. Exposed in the various quarries and at many places from the Charlevoix Rock Products Co. quarry westward to the lake shore	45
Soft blue shale. Exposed in the bottom of the Charlevoix Rock Products Co. quarry No. 1	10
Series of high calcium limestones with some very siliceous and argillaceous beds. Exposed north of Charlevoix Rock Products Co. quarries along lake shore and on Pine River Pt	40+

Norwood. North of Norwood, limestone is exposed along the shore on old terraces 40 to 60 feet or more above the water. The exposures or areas of easily accessible limestone are relatively small, being confined to the narrow terraces. Inland the overburden becomes excessive. Immediately south of Norwood the limestone is overlain by the black shales of the Antrim formation.

One mile north of the dock at Norwood, sec. 34, T. 33 N., R. 9 W., heavy magnesian limestone is exposed in a low bluff near the lake shore. Analysis No. 160, made by Rominger in 1869, shows that it is practically dolomite.

About $1\frac{1}{2}$ miles northeast of Norwood, NE. $\frac{1}{4}$ section 26, T. 33 N., R. 9 W., high calcium limestone is exposed in a number of places along the top of one of the upper terraces and at the base of a series of ancient sand dunes. The area of the terrace at this point is considerable but the area of accessible limestone could not be determined. Apparently it is at least several acres. About 5 feet of light gray dense grained to lithographic limestone was exposed in two small openings formerly operated for lime burning. Other openings are reported in this vicinity but these were not discovered. Nothing could be learned as to the probable thickness of this bed. Analysis No. 161 from a composite of several representative samples is indicative of its high average purity. It is possible that a considerable acreage of this high calcium stone could be developed in this locality.

Bay Shore. A double line of terraces or old lake beaches extends along the south shore of Little Traverse Bay. The lower terrace ranging from a few feet up to 40 feet or more in height is generally very close to shore. The upper terrace of equal height is usually from a few hundred feet to a half mile distant. Due to wave cutting by the present lake, limestone cliffs occur at many places in the lower terrace from Bay View, Emmet county, westward to Charlevoix and beyond. The upper terrace has but few exposures, being largely drift covered.

At Bay Shore cliffs of friable or sugary yellow brown limestone varying from a few feet to 40 feet or more in height extend continuously

along the shore for a considerable distance. Here the lower terrace is several hundred feet wide but the overburden is relatively thick in most places.

Northern Lime Co. quarry. Bay Shore or Standard Plant. The Northern Lime Co. of Petoskey operates a number of quarries along Little Traverse Bay for lime burning. Their plant at Bay Shore is called the Bay Shore or Standard Plant. The quarry is double, consisting of an eastern and western portion with a battery of four kilns midway between. At the time of the writer's visit the western opening was the smaller and shallower but plans were then under way for cutting through the neck separating the quarries. The developed face in the smaller quarry ranges in height from 15 to 25 feet but in the other it is 35 to 40 feet. The overburden is relatively thick, varying from 3 to about 10 feet, the thickness increasing away from the shore.

Locally the strata show very discordant dips. The general dip is slight and almost due south yet in the smaller quarry it averaged 5 degrees N. 45° W., resulting in a pronounced inclination of the quarry floor. Larger dips were observed but these were not maintained throughout the quarry. In the eastern quarry the dip, though not measured, was strongly to the northwest as in the smaller quarry. A quarter of a mile west of the quarry the dip is about 10° in the same direction. At Kawgachewing Point two miles farther west apparently corresponding strata are higher than at Bay Shore, therefore a marked syncline is indicated between these two places.

The following section was exposed in the western quarry:

Section in Bay Shore quarry, west end.

		Feet.
	Surface	3 to 6 +
1.	Light gray to white dense grained limestone, harder than the strata below	3 +
2.	Very yellow and ferruginous limestone, worthless and rejected for lime burning	1
3.	Yellow to brown laminated limestone	2
4.	Massive yellow limestone, very soft in upper portion	3
5.	Banded yellow limestone with bituminous bands	2 +

In the eastern quarry bed No. 1 is overlain by 2 to 3 feet of gray crystalline magnesian and siliceous limestone, resembling at a little distance, gray granite and so termed by the quarrymen. The bed is rejected for burning. The remainder of the section is similar to that in the western quarry, but a much greater thickness of the lower, yellow, sugary limestones is exposed, the working face of the quarry being from 35 to 40 feet.

On the northeastern side of the quarry the strata down to and into the yellow limestone is cut out by a "horse of sandstone." It is a massively bedded yellow sandy appearing lime-sandstone said to con-

tain only about 56 per cent of calcium carbonate and to be worthless for lime. This so-called "horse of sandstone" apparently represents an eroded channel in the limestone filled with lime-sand. The presence of this stone has stopped further quarrying on that side of the quarry.

Bed No. 1 is said to be "good" limestone, but No. 2, the ferruginous bed, is worthless. The yellow, "sugary" limestones below this bed are largely magnesian but are said to burn well and make very satisfactory commercial lime, containing from about 75 to 85 per cent of calcium oxide. Analysis No. 162 is of a representative set of samples from the usable stone in the quarry and indicates the general magnesian character of the beds. As at Petoskey and Superior (2 mi. west of Bay Shore) the percentage of calcium carbonate increases downward though irregularly.

Determinations of calcium carbonate were made for eight strata from top to bottom with the following results:

Analyses of limestone beds at Bay Shore.

No. analysis.	No. of bed.	$CaCO_3$.
166	1. (top)	63.03
167	2.	82.45
168	3.	79.77
169	4.	92.44
170	5.	88.34
171	6.	97.97
172	7.	93.33
173	8.	63.71

Analysis No. 163 is said to be from a high calcium bed near the base of the quarry. Analyses 164 and 165 are of commercial lump lime. The low content of silica, alumina, and iron in the stone as quarried is noteworthy. Analysis No. 174 is by Rominger from dark lithographic limestone about one mile east of Bay Shore and presumably from near the water edge. Very probably these lithographic beds are but a short distance below the bottom of the Bay Shore quarry as they are exposed on either side along the shore.

Owing to the soft friab e nature of the stone it is not adapted for concrete, roadmaking, or ballast.

Superior. At Superior, about 2 miles west of Bay Shore, the yellow sugary limestones form the upper terrace, the base of which is between 30 and 40 feet above the lake. The general character of the beds in the lower terrace is not known, but near the top there is a bed of blue shale and shaly limestone, and at the bottom slightly above and also below water level, there is a light gray lithographic bed overlain

by gray, dense grained to crystalline and fossiliferous limestone. These lower beds are high calcium limestones according to the local lime burners and apparently they belong to the series of high calcium lithographic limestones exposed at a number of places along the lake shore near water level from Petoskey westward nearly to Bay Shore.

Northern Lime Company, Superior Plant. The Northern Lime Company operates a quarry in the upper terrace of sugary limestones for burning lime. The quarry has been developed parallel to the face of the terrace or bluff and is about 600 feet long. The working face varies from 30 to 35 feet in height. The overburden is largely sand and stony gravel and varies from 2 to 10 feet thick. Apparently it is relatively thin over a considerable area back from the lake. The quarry supplies stone for a battery of three continuous kilns. Owing to its soft friable nature the stone is not suitable for concrete, road making, and ballast.

The section exposed in the quarry is as follows:

Section in Superior quarry.

		Feet.
	Surface sand and gravel	2 to 10
1.	Yellowish white dense grained to earthy limestone	6+
2.	Clayey or shaly light yellow limestone disintegrated and "rotten"	2
3.	Earthy limestone with light yellow and gray mottlings and streaks. More crystalline toward the bottom	10
4.	Massive earthy yellow limestone	7
5.	Banded brownish "sugary" limestone with bituminous bands. Bottom of this bed forms the floor of the quarry	2+
6.	Blue very shaly limestone weathering yellow	1+

The beds, though magnesian, are much less so than at Bay Shore as shown by analysis No. 175. According to Mr. Zipp, superintendent of the Superior and Bay Shore plants, lime averaging 85 per cent calcium oxide can be obtained by sorting the stone. Analysis No. 176 by Rominger in 1869 is from one of the dark lithographic beds near the bottom of the lower terrace and indicates that they are exceptionally high in calcium carbonate. The stone, however, is not adapted for lime burning on account of its tendency to "pop" or break to pieces in the kiln, thus choking the draft.

West of Superior and Kawgachewing Point cliffs of limestone similar in character to that at Superior occur at one or more points along the lake shore but the extent of the accessible limestone is uncertain. Generally ancient sand dunes and glacial deposits limit the quarryable areas to small narrow benches near the shore.

Summary. The limestone resources of Charlevoix county are chiefly confined to relatively small areas along the lake shore in the form of narrow benches, the inland portions of the county generally being

heavily drift covered. The largest and most important area occurs between the city of Charlevoix and Lake Michigan. The limestone in this area is high calcium but that eastward along the lake shore from Charlevoix is largely low to high magnesian. An area of high calcium stone occurs north of Norwood but its extent and importance is uncertain.

Cheboygan County.

Distribution. Three limestone formations underlie Cheboygan county. The Monroe formation skirts the lake shore on the north, the Dundee limestone forms a narrow parallel belt immediately south, and the Traverse formation occupies the whole central portion of the county. The Antrim and the Coldwater shales underlie the southern portion.

The rock surface is cut by a system of deep valleys partly drift filled and partly occupied by lakes. The deepest and largest extends from Cheboygan southwest to Little Traverse Bay and is occupied by Mullet, Burt, and other lakes. Black Lake occupies a branch of this valley extending southeast from Cheboygan. Due to the deep valleys and the irregular deposition of the drift, the exposures of limestone are chiefly on the sides of river valleys or along old glacial lake beaches and are usually of limited extent. The numerous drift filled channels locally makes the development of limestone deposits uncertain and hazardous.

The Monroe formation is doubtfully exposed near the water's edge on the lake shore east of Mackinaw City. The Dundee limestone forms the upper terrace along the lake shore from section 30, T. 39 N., R. 3 W., eastward across Private Claim No. 334, a distance of about three miles. Exposures occur along the lower course of Mill Creek which flows across the claim. The Traverse formation is exposed in numerous bluffs along river valleys in the vicinity of Afton, Legrand, and Tower.

The Dundee limestone as exposed in Cheboygan county is essentially a high calcium formation with a magnesian base. The Traverse formation is less shaly than in Alpena county but more so than in the vicinity of Little Traverse Bay.

Quarries and Localities.

Afton quarry. At Afton in NW. ¼ NE. ¼ section 36, T. 35 N., R. 2 W., the Campbell Stone Company operates a quarry (Pl. III A) both for lime burning and for crushed stone products. The quarry has been opened in the upper part of a high bluff on the east side of Pigeon River valley. The quarry is a more or less oval opening several hundred feet long and 30 to over 40 feet in depth.

The area of easily accessible stone was not determined but it is large

A. PLANT OF THE CAMPBELL STONE COMPANY AT AFTON, CHEBOYGAN COUNTY.

B. QUARRY OF THE PETOSKEY CRUSHED STONE COMPANY FOUR MILES WEST OF PETOSKEY, EMMET COUNTY.

Pronounced undulations of the beds as shown at the left are characteristic of the Traverse formation along Little Traverse Bay.

since a half mile to the north limestone is at or near the surface. The ridge, which forms a bluff along the river valley, extends eastward past the village of Afton for a considerable distance.

The section exposed in the quarry is as follows:

Section in Afton quarry.

			Feet.
	Glacial drift		0 to 2 +
1.	Light gray dense grained to crystalline limestone. $CaCO_3$, 97.32%		5
2.	Black bituminous limestone with masses of cup corals. Much of the stone rejected though high in calcium carbonate. $CaCO_3$, 92.6%. Organic matter 2.61%		6
3.	Light gray crystalline limestone. Very pure and burns easily. Used chiefly for paper manufacture by the soda process, $CaCO_3$, 96.97%		4 +
4.	Disintegrated limestone. Falls to pieces in quarrying		1 −
5.	Very bituminous, banded, thin bedded limestone with bituminous bands. Parts readily along bituminous bands.	$CaCO_3$, 98.04%	2½
6.	Similar to No. 5, but less bituminous. More bituminous near top.		5½
7.	Badly disintegrated or "vesicular" bed; belongs to bed below. Stone breaks into fine pieces in quarrying		2 −
8.	Very porous vesicular limestone. Openings due to solution. Stone breaks up badly, resulting in much waste.	$CaCO_3$, 95.75%	4
9.	Light gray to buff fine grained limestone; main quarry beds. Stone used for lime obtained largely from this bed.		10
10.	Light gray to grayish buff limestone with thin shale parting at top		2
11.	Vesicular limestone, the floor in part of the quarry		1 +

A core drilling* near the quarry gave the following section:

Core Drilling, Afton Quarry.

	Thickness, feet.	Depth, feet.
Clay, sand and broken rock	4	4
Light colored rock	38	42
(This forms the quarry beds. Near the lower south side of the quarry the black limestone (No. 2) is not present and the fact that this conspicuous bed was not noted in the record indicates that the hole was near the south edge of the bluff, hence the 38 feet of light colored limestone probably does not include beds No. 1 and No. 2).		
Brown rock, soft. (This is probably the soft vesicular limestone which forms the bottom of the quarry)	6	48
Light limestone, hard	6	54
Dark limestone, soft	1	55
Dark limestone, hard	1	56
Blue shale, soft	5	61
Black limestone, hard	1	62
Light limestone, soft	2	64
Black limestone, hard	1	65
Light limestone, soft	1	66
Mixed dark and light limestone, hard	13	79
Light limestone, hard	4	83
Gray limestone, hard	5	88
Mixed dark and light limestone, hard	7	95
Black limestone	5	100

Several other holes drilled in the vicinity of the quarry show practically the same section. Undoubtedly the holes located farthest north show the presence of beds No. 1 and No. 2, which were encountered farther up the bluff during the progress of quarrying in this direction.

*A. C. Lane, Appendix Annual Report, 1908, Michigan Geological Survey, p. 91.

Character. The quarry beds vary greatly in color, structure and texture but all are very high in calcium and correspondingly low in magnesia. The black limestone owes its color to 2% to 3% of organic matter. As a rule, all but the more fossiliferous and less bituminous portions of this bed are rejected. The vesicular structure is apparently due to solution from water. In portions of some of the beds, the solution channels are so numerous that the stone literally crumbles to pieces under the heel. Blasting reduces this stone to an unsalable mass of small fragments. The percentage of fine material is exceptionally large and ordinarily would be wholly waste. Lime is burned in a rotary kiln and the stone must be crushed into small fragments, hence much of the fine material can be directly utilized for lime.

Bed No. 3, on account of its exceptionally low percentage of impurities, particularly silica and magnesia, is especially adapted for sugar and paper making. It burns very easily and makes a most excellent lime, but owing to the demand by paper and sugar manufacturers for stone from this bed most of the stone used for lime is obtained from beds Nos. 8, 9 and 10, which burn less easily, though making an excellent hot lime.

The percentage of calcium carbonate in the different beds in the quarry ranges from about 93% to over 98% (bed No. 3) and the silica from a minimum of .24% in the upper beds to 1.75% for the lower beds as shown by analyses Nos. 177 to 181. The average of analyses (No. 184) made from every two feet of core, the top 38 feet of "light colored" limestone (below beds Nos. 1 and 2) gave 96.52 per cent of calcium carbonate and 2.10 per cent of silica. Below this depth the silica and magnesia increase, a similar average of analyses (No. 185) gave 3 to 5 per cent of silica and 6 to 9 per cent of magnesia. Analysis No. 182, said to be of black limestone, shows a surprisingly small amount of organic matter as compared with analysis No. 178 of bed No. 2.

The presence of the bituminous and the vesicular beds in the quarry requires hand sorting and loading. The product is burned for lime, and sold for a variety of purposes requiring high calcium limestone.

Black Lake Quarry. A number of years ago the Onaway Limestone Co. opened a quarry in sec. 2, T. 35 N., R. 1 E., in a bluff along the south side of Black Lake about 6 miles north of Onaway. The following section is exposed:

Section in Black Lake quarry.

		Thickness, feet.
1.	Dark bituminous, crystalline, and very fossiliferous beds, containing masses of corals and an abundance of brachiopods. The beds are present only at the east end of the quarry	0-6 +
2.	Light gray dense grained limestone with small disseminated calcite crystals	8 +
3.	Dense grained gray limestone with but few crystals of calcite	7
4.	Gray dense grained limestone with many small calcite crystals	9
5.	Dense grained gray to lithographic limestone with many small crystals of calcite. Lighter than beds Nos. 3 and 4	4
6.	Very fine grained, dark bituminous limestone	1 −
7.	Dense grained gray to lithographic limestone similar to No. 5	4
8.	Dense grained limestone with bituminous bands	1½
9.	Dense grained limestone with calcite crystals and dense cavities	1
10.	Dark argillaceous bituminous and fossiliferous limestone with druse cavities. Apparently the top of the Long Lake series	1 +

The dip is strongly to the southeast and the light gray fine grained beds of the quarry are overlain on the east by gray fossiliferous and more argillaceous beds.

An analysis, No. 186a, of a set of samples from the light gray fine grained beds gave 96.84 per cent of calcium carbonate, 2.03 per cent of magnesium carbonate and less than 1 per cent of impurities. The beds weather to a distinct buff or brown, indicative of the presence of iron. The stone was sold for sugar manufacture but apparently the percentage of magnesium is slightly too high. The low percentage of impurities make the stone suitable for blast furnace flux and for use in the chemical industries.

Legrand quarry. About three-fourths of a mile southeast of Legrand in the SE. ¼ sec. 28, T. 35 N., R. 1 W., the Campbell Stone Company opened a test quarry in a prominent ridge of limestone. The ridge extends in northwest-southeast direction and terminates on the north in a cliff or bluff, from 10 to 40 feet or more in height, along which exposures of limestone occur. The overburden at the brow of the cliff is thin but apparently it is much thicker to the south. The strata exposed in the quarry dip strongly to the south. The Legrand branch of the Detroit and Mackinac railroad passes directly in front of the quarry and affords favorable transportation facilities.

The section exposed in the quarry is identical with that at Afton, though the two places are nearly four miles apart, hence description of the beds is unnecessary. The section exposed is about 32 feet.

To the northwest the ridge is broken by a small stream but is continued in sec. 19, T. 35 N., R. 1 W. The record of a core drilling made on the SW. ¼ SE. ¼ of this section is as follows:

Core drilling Sec. 19, T. 35 N., R. 1 W.

	Thickness, feet.	Depth, feet.
Surface	2	2
Light colored limestone	5	7
Light colored limestone	8 6 in.	15 6 in.
White coral limestone	1 6 in.	17
Light limestone	4	21
White coral limestone	2 6 in.	23 6 in.
Light limestone	2	25 6 in.
White coral limestone	6 in.	26
Light limestone	4 6 in.	30 6 in.
Dark limestone	2	32 6 in.
Light limestone	6 6 in.	39
Dark rock	1	40
Blue shale	8 6 in.	48 6 in.
Gray shale	2	50 6 in.

An average (Anal. No. 186) of analyses made every two feet to the depth of 30 feet 6 inches gave 94.20 per cent calcium carbonate and 3.40 per cent of silica. Other core drillings were made on SW. ¼ NE. ¼ sec. 25, T. 35 N., R. 2 W., also on NW. ¼ SW. ¼ and SW. (?) ¼ SW. ¼ of sec. 13, T. 34 N., R. 2 W., and the results were very similar to those of the two records given above.

Marion Stone Co. quarry. Formerly the Marion Stone Company operated a small quarry in the S. ½ NE. ¼ sec. 7, T. 35 N., R. 1 W., on the south side of a prominent ridge of limestone extending roughly in a NW-SE direction across the section and terminating on the southwest in a steep slope toward a small branch of Pigeon river. Rock is exposed along the brow of the ridge in a number of places. The overburden in the vicinity of the quarry varies from 1 to 3 feet. A branch of the Michigan Central railroad passes close to the quarry and affords ready facilities for marketing the product.

The opening is 300 to 400 feet long and very narrow. The beds dip strongly to the southeast and unfortunately quarrying was developed nearly in the direction of the dip. This made bad drainage conditions and a very rough floor. As quarrying progressed a 6-foot black bituminous limestone was encountered which contained so much organic matter and other impurities as to be unmarketable. These adverse conditions finally caused the abandonment of the quarry.

The section exposed is as follows:

Section in Marion Stone Co. quarry.

		Thickness, feet.
	Surface	1-3
1.	Densely crystalline limestone, fossiliferous in places	4
2.	Very fossiliferous limestone with bands of very fine grained limestone, showing "ribbon" structure on weathered surface	3½
3.	Dense grained to crystalline limestone with abundance of corals and brachiopods in places	5
4.	Gray crystalline limestone	1½
5.	Light gray densely crystalline and fossiliferous limestone	4
6.	Black bituminous limestone with scattering cup corals. Burns hard and larger pieces generally have a black carbonaceous core	6
7.	Vesicular limestone. Cavities due to solution. Lowest bed exposed in quarry	2½ +

According to analysis No. 187 made from a representative set of samples from the various beds with the exception of the black limestone, the average content of calcium carbonate is nearly 97 per cent. The vesicular beds when below the water table yield large quantities of water. For this reason quarrying operations must be confined largely to the bluffs where the strata are self draining.

Limestone is exposed on numerous ridges and hills in the vicinity of Afton and Legrand and apparently there are large areas where limestone is under very favorable conditions for quarrying.

Tower. At Tower, limestone is exposed in a series of ledges in the channel of Black river, giving rise to rapids. Twelve feet of dark gray, nodular to massive, crystalline and fossiliferous limestone resembling the Long Lake series of the lower Traverse are exposed on the south side of the stream. The area of limestone under light cover is apparently small. No analyses are available.

Durrell or Mill Creek quarry. Four miles southeast of Mackinaw City, in Private Claim No. 334, the Dundee limestone is exposed along the lower course of Mill Creek and old lake terraces rising about 80 feet above Lake Huron. The upper terrace is covered with drift from 4 to 30 feet or more in depth. Mill Creek has carved a relatively wide valley in the drift on the terrace and a very narrow one in the limestone below, thus exposing the limestone in the creek bed in narrow benches on the sides of the lower valley. Limestone is also exposed along the base of the upper terrace parallel to the lake shore.

The Cheboygan County Limestone Products Company have recently opened a small quarry near the mouth of the creek. The following section is exposed:

Section in Durrell quarry, Mill Creek.

		Thickness, feet.
	Surface clay	4-8 +
1.	Hard white limestone, top magnesian bed. $CaCO_3$ 82.62 per cent, $McCO_3$ 16.97 per cent	1-2
2.	Buff to gray bituminous crystalline limestone with some very fossiliferous (Coralline) beds and bands of black bituminous limestone, $CaCO_3$ 98.45 per cent, $MgCO_3$ 1.24 per cent	12
3.	Buff to gray crystalline limestone, middle magnesian bed. $MgCO_3$ 5.98 per cent	3 ±
4.	Buff to gray bituminous and crystalline limestone with bituminous and fossiliferous bands. $CaCO_3$ 98.61 per cent, $MgCO_3$ 1.18 per cent	9½
5.	Buff to gray limestone $CaCO_3$ 96 ± per cent. Analyses available only from a portion of this section. Floor of quarry	10
6.	Light to dark buff bituminous and more or less friable and sugary limestone with gray crystalline spots. Locally very fossiliferous. Basal magnesian beds of the Dundee limestone. $CaCO_3$ 69.40 to 75.80 per cent. Thickness above lake level about	25

The area of limestone exposed or under light cover in Mill Creek valley and on the lower terrace is relatively small. Test holes indicate that the surface of the limestone is cut by valleys and gullies hence the total area of easily accessible high calcium stone is uncertain. The thickness of the stone above the basal magnesian beds is variable, ranging from nothing to probably over 50 feet. The average is probably between 30 and 40 feet.

The beds are characteristically gray to buff in color and very bituminous. Where fresh the stone is gray and crystalline, but where weathered it has a yellow or brown sugary appearance. Locally there are dark to black bituminous streaks. Most of the beds are sparingly fossiliferous but some are a mass of fossils, cup corals predominating. Locally the rock is fractured and the cracks are filled with bright red clay apparently the result of infiltration from the red surface deposits.

Analyses have been made of a large number of samples taken from the numerous exposures along the banks of Mill Creek from drill cores and from the quarry face and these show that most of the upper 45 feet averages over 98 per cent calcium carbonate with very little silica, iron and alumina or magnesia. The exceptional purity of these beds is shown by analyses Nos. 188, 190-193, 195-211, 213-216 and 218-227z. There are, however, magnesian bands, one near the top of the quarry and one near the middle as shown by analyses Nos. 194, 212, and 217. The basal beds of the Dundee, however, contain from considerable to large percentages of magnesia as shown by analyses Nos. 189 and 228.

On account of its exceptional purity, the stone is especially adapted for general fluxing purposes and for the manufacture of Portland cement, sugar, carbide and for use in the soda ash and chemical industries. The stone in the upper crystalline bed is generally hard and is suitable for road making, concrete and ballast.

The Michigan Central railroad runs directly in front of the quarry, affording favorable shipping facilities.

Limestone is exposed at various points along the high terraces to the northwest to McGulpins Pt. west of Mackinaw City. About two miles south of Mackinaw City in secs. 29 and 30, T. 39 N., R. 3 W., low ledges of Dundee limestone are exposed in the fields. Formerly lime was burned in small kilns at a number of places. The upper beds about 10 feet thick belong to the high calcium series at Mill Creek. Test holes show, however, that the basal magnesian limestone of the Dundee occurs at very shallow depths in the vicinity of the exposures. The upper lake terrace in these sections has in most places a heavy cover of drift.

Summary. Exposures of the Traverse formation are numerous in the central part of Cheboygan county in the form of relatively flat topped bluffs and ridges along river valleys. The extent of the accessible limestone is uncertain but apparently large. Test borings indicate that shale is very subordinate in amount and that the beds of limestone are uniformly high in calcium carbonate. Exposures of the Dundee limestone are small and limited to the narrow valley of Mill Creek and to the lake terraces between McGulpins Pt. and the mouth of Mill Creek.

Chippewa County.

Distribution. Chippewa county is underlain by three limestone formations, viz.: Beekmantown (Calciferous), Trenton, and Niagara.

The Beekmantown is exposed only in the vicinity of Neebish Island, the Trenton on St. Mary's river, Carp river south of Waiska bay, and in the hills extending northwest-southeast through Ts. 45 and 46 N., R. 1 W. The Niagara is exposed over large areas on Drummond Island, in the southeastern peninsula, and along the southern margin in the western part of the county.

Beekmantown (Calciferous) formation. Ledges of Beekmantown formation are exposed on the west shore of Neebish Island. The rock is described by Rominger* as a hard crystalline dolomite in beds 6 to 12 inches thick divided by vertical fissures into almost rectangular blocks. Apparently it would make a durable building stone. Analysis No. 229 by Rominger indicates that it is practically a normal dolomite, though siliceous. Exposures also occur on St. Joseph and Encampment d'Ours islands on the Ontario side of the river where limestone was formerly quarried on a small scale. The exposures of the Beekmantown are of little economic importance in this county.

Trenton Limestone. The exposures of the Trenton limestone are all

*C. Rominger, Vol. I, Pt. 3, p. 76, 1869-1873, Michigan Geological Survey.

on the Canadian side of the river, on St. Joseph, Encampment d'Ours, and Sulphur Islands. About 60 feet of shales and limestones belonging to the Trenton are exposed on Encampment d'Ours island. The lower portion is largely sandy calcareous shales, the middle part is thin bedded nodular limestone with shaly streaks, and the upper part is light colored brittle limestone with a conchoidal fracture. Analysis No. 230 by Rominger* indicates that the upper limestone though low in magnesia is siliceous. The beds exposed in the spur forming the northeast end of St. Joseph island are identical with those of Encampment d'Ours. Analysis No. 231 is from the blue middle argillaceous limestone and analysis No. 233 from the lower blue sandy portion.

Niagara Limestone. Exposures of all four members of the Niagara limestone, viz., the Engadine dolomite, the Manistique series, the Fiborn limestone, and the Hendricks series occur in Chippewa county. The principal exposures of the Engadine dolomite are in the northern third of T. 44 N., Rs. 4 and 5 W., the southwestern corner of T. 43 N., R. 1 E., the southern part of T. 43 N., R. 3 E., and in T. 42 N., Rs. 2, 3 and 4 E. This member caps most of the high bluffs, hence exposures of the underlying Manistique series are numerous along the basal portions of the bluffs. The most extensive exposures of the Manistique series are on Drummond Island. Exposures of the Fiborn limestone are doubtful but the Hendricks series is well exposed at Marble Head on the eastern shore of the island and also on some of the islands in St. Mary's river. The Fiborn limestone is exposed or under light cover at several places west of Trout Lake in the western part of T. 44 N., R. 6 W. Elsewhere the Fiborn limestone and Hendricks series are deeply buried under glacial drift.

Quarries and Localities.

Marble Head, Drummond Island. This locality was not visited by the writer, hence its description must rest upon the authority of Rominger† who has described it in detail. Marble Head is a promontory at the eastern end of Drummond Island rising about 100 feet above lake level. Its sides are steep with occasional vertical cliffs. Owing to the southward inclination of the beds, lower lying beds are brought to the surface on the north side of the hill along the shore. The following is the section as given by Rominger:

*C. Rominger, Vol. I, Pt. 3, pp. 64-68, Michigan Geological Survey.
†C. Rominger, Vol. III, pt. 3, pp. 33-36, Michigan Geological Survey.

Section at Marble Head, Drummond Island.

	Thickness, feet.	Depth, feet.
1. Light colored irregularly bedded crystalline magnesian limestone	25	25
2. Massive light cream colored obscurely bedded coarsely crystalline dolomite, filled with casts of Pentamerous oblongus	15	40
3. Finer grained, more thinly and regularly bedded dolomite	4	44
4. Drift covered	10	54
5. Dark gray highly crystalline limestone with siliceous veins containing many fossils. Top of quarry	6	60
6. Dull earthy light colored laminated limestone, becoming non-fossiliferous toward the bottom	15	75
7. Dark gray crystalline limestone becoming earthy toward bottom of quarry	8	82
8. Dark gray bituminous dolomites of nodular and unhomogenous structure. Seams of black carbonaceous matter wind about in the rock mass	10	92
9. Flaggy layers, in various shadings of color and with nodular surface	6	98
10. Ash colored fine grained acicular limestone in beds 4 to 8 inches thick, some of which are full of fissure-like cavities extending in all directions. Cavities apparently once occupied by tabular crystals of calcite $CaCO_3$ 95 per cent. (This may be the diminished representative of the Fiborn limestones)	3	101
11. Dull earthy limestone, druse cavities filled with calc-spar or quartz. Some of the beds quarried on a small scale, but apparently do not resist the weather very well	8	109
12. Dark gray bituminous and nodular limestone. The nodules are coated with a black film of bituminous shaly matter	5	114
13. Light colored absorbent limestones, separating in thin slabs with uneven conchoidal surface. This exposure is one-fourth mile from Pirate Harbor	10	124

Beds Nos. 5 to 9 inclusive were exposed in an old quarry at Marble Head, analyses Nos. 234 to 236 by Rominger show that they approach normal dolomite. Bed No. 11, the acicular limestone below the floor of the quarry and the light colored absorbent limestones at the bottom of the section are high in calcium carbonate, as shown by analyses Nos. 237 and 238. Analyses No. 239 is from loose slabs thrown up by the water on the west side of Sitgreaves bay. These slabs are apparently from just above the Cincinnati (Hudson River) group.

Further exploration inland to the northwest along the strike of the beds might result in the discovery of important exposures of the high calcium beds.

Drummond. A double series of high terraces or bluffs occurs along the north shore of Drummond Island in the vicinity of Drummond. Limestone is exposed at several places in vertical cliffs. The upper terrace, 10 to 40 feet in height, is composed of an alternating series of buff crystalline and fossiliferous high magnesian limestone, and dense grained, thin bedded dolomite without fossils. The lower terrace, 30 to 40 feet in height, is composed of buff to gray, finely crystalline and massively bedded dolomite. Vertical fracture systems almost at right angles to each other result in natural rectangular blocks of large size.

Due to this fact and to the hardness of the rock large quarries have been operated for block stone for use in constructing the earlier ship canals at the "Soo" and in building breakwaters and piers on the Great Lakes. Formerly these dolomites were used extensively in burning magnesian lime one mile east of Drummond on the lake shore. According to local residents the stone burned hard and produced a gray lime, not well suited for ordinary purposes.

The area of easily accessible natural block stone is limited to a narrow bench from a few rods to several hundred feet in width between the lake shore and the upper terrace. The area underlain by the fossiliferous and non-fossiliferous limestones of the upper terrace is very large. Exposures are numerous at many places in the vicinity of Drummond.

The following section is exposed in the L. Seaman quarry and on the bluffs immediately back of the quarry:

Section in L. Seaman quarry, Drummond.

		Thickness.	
		Feet.	Inches.
	Surface	0 to 3	
1.	Light grayish buff crystalline and fossiliferous magnesian limestone. Abundant casts of Pentamerus oblongus. Only about 4 feet of rock exposed; basal portions of bed concealed by talus	8 +	
2.	Similar rock composed largely of casts of Pentamerus forms. Only about 3 ft. of stone exposed; other beds may be present between this and the next succeeding	15 ±	....
3.	Similar, but fossils less numerous and the stone less crystalline. Only about 5 ft. of rock exposed. Other beds may be present	15 ±	....
4.	Buff very dense grained and thinly bedded dolomite, resembling novaculite and having a prominent conchoidal fracture. Much like some of the dense grained finely crystalline dolomites in the quarry below. Only upper 6 feet exposed. Other beds may be present. Top of quarry	25 ±	....
5.	Buff to gray cherty, and massively fossiliferous dolomite	3	6
6.	Hard light gray to buff massive and crystalline dolomite, separated from No. 7 by a parting of very thin bedded dolomite	3	....
7.	Hard light buff massive and crystalline dolomite similar to No. 6	4	8
8.	Hard buff densely crystalline dolomite—conchoidal fracture prominent in lower part of bed	8	....
9.	Dark buff crystalline dolomite with a drusy fossiliferous zone in the center of the bed	3	6
10.	Hard light gray to buff finely crystalline banded dolomite with prominent bedding planes	7	8
11.	Hard bluish fine grained dolomite weathering to a pronounced blue color. Lowest bed quarried and floor of quarry is apparently a part of the same bed and just above lake level	2 +	....

A similar section is exposed in a large quarry on Quarry Point about one mile west of the above. This quarry, like the Seaman quarry, was formerly operated for block stone. The massive crystalline beds in the lower terrace are dolomite as shown by analysis No. 240.

Old Fort Drummond. In the vicinity of Old Fort Drummond at the southwest extremity of Drummond Island there are numerous exposures

of magnesian limestones belonging to the upper part of the Manistique series and probably the tops of some of the higher elevations are capped with Engadine dolomite. Large exposures of the Manistique series occur along the south shore of the island as at the head of Huron Bay and on the peninsulas between Huron Bay and Scammon's Cove.

Lime Island, St. Marys River. A few hundred feet north of the Pittsburgh Coal Co. docks on Lime Island a quarry was operated many years ago for burning lime. The stone was obtained from a narrow bench which rises 30 feet above the river level. Apparently hard rock forms part of an upper terrace rising 25 or 30 feet higher. The stone is white to buff finely crystalline normal dolomite as indicated by analysis No. 241. According to statements of local residents the stone burned hard and produced a gray slow setting lime not well suited for ordinary uses.

In digging a trench for the steam mains from the engine house to the company quarters many pieces of limestone identical in physical characteristics with the Fiborn limestone were observable in the drift. The angular uneven character of the fragments indicates the close proximity of this member and it is possible that it forms a portion of the upper terrace. The fact that the white to buff dolomites of the quarry in the lower terrace resemble those which occur beneath the Fiborn limestone in the Hendricks quarry in Mackinac County also tends to support such a possibility. No exposures, however, could be found.

Detour. Large exposures of Engadine dolomite occur in and about the village of Detour. Quarrying and transportation facilities are exceptionally favorable at this place. The dolomite is massive and coarsely crystalline and where fresh shows the peculiar bluish mottlings and streaks so characteristic of this member. Where weathered the rock is white. In the northern part of the village a small quarry was formerly operated for lime burning. The low percentage of silica, iron and alumina in analysis No. 242 made by Rominger in 1873 is characteristic of this dolomite.

Gatesville. Prominent ridges of bare limestone occur between Gatesville and Point Detour. The ridges are capped by Engadine dolomite, but the bases are formed of the upper very fossiliferous dolomite beds of the Manistique series. The high ridge of dolomite just east of Gatesville extends north almost to Raber on St. Marys River.

Rockview. Rockview is at the top of high northward facing bluffs capped with the typical bluish mottled and streaked and coarsely

crystalline dolomite of the Engadine member. The fossiliferous, thin bedded dolomites of the Manistique series form the base of the bluffs and are extensively exposed. Owing to the gentle southward dip of the strata the capping of Engadine dolomite extends southward to Cedarville, Mackinac County, on the lake shore.

Sec. 8, T. 43 N., R. 2 E. Ledges of very massive coarsely crystalline dolomite with the characteristic mottling and bluish colorations of the Engadine dolomite occur here and there in this and adjacent sections. Large tracts are covered with great boulders of this dolomite Analysis No. 243 shows the characteristic purity of this stone.

Haff P. O. (Dick). At Haff a line of limestone bluffs 10 to 80 feet or more in height extends south nearly to Kenneth, Mackinac County and eastward for many miles. The tops of the bluffs generally have only a light cover of drift and tracts covered with great boulders are characteristic. The upper 40 to 50 feet of the bluffs is composed of Engadine dolomite, extremely massive, coarsely crystalline, and mottled and streaked with blue. The base is composed of the thin bedded and very fossiliferous dolomites of the Manistique series.

The area underlain by easily accessible dolomite in the vicinity of Haff and in the southern portions of T. 44 N., Rs. 4 and 5 W., is apparently several square miles. Analysis No. 246 was made from a set of samples taken from the property of L. O. Poquin at Haff and may include samples from the underlying Manistique dolomites. The content of iron and alumina indicates this. Analyses Nos. 244 and 245 are respectively from the lower and upper parts of a 50 foot exposure of Engadine dolomite three-fourths of a mile south of Haff, where the road from Trout Lake to Ozark crosses the bluffs. Both of these analyses are characteristically low in silica, iron and alumina. Owing to the low percentage of these impurities this stone is particularly adapted for lining open hearth furnaces. Its porosity as well as purity also adapts it for use in the manufacture of paper by the sulphite process.

Sec. 19, T. 44 N., R. 6 E. About three miles west of Trout Lake in section 19 and adjoining sections, T. 44 N., R. 6 E., exposures of Fiborn limestone are reported. The writer found many boulders of lithographic limestone similar in every particular to the Fiborn limestone, but could not determine whether or not some very small ledges were actually in place. The Fiborn member occurs just across the county line to the west in Mackinac County, therefore it is probable that further search might result in the discovery of quarryable areas of this stone.

Summary. Large areas along the southern margin and in the southeastern part of Chippewa county are underlain by thick beds of exceptionally pure dolomite belonging to the Engadine member. Quarrying conditions are very favorable at many places. The stone on account of its purity is especially suitable for lining open hearth furnaces. Its purity and porous character also make it particularly adapted for paper manufacture. The supply of this stone is practically inexhaustable.

The beds of dolomite on Drummond Island are of great extent but they are less pure than those on the mainland. Further exploration between Maxton and Marble Head may result in the discovery of considerable, or even large areas of high calcium limestone, similar to that exposed immediately north of Marble Head.

Delta County.

Distribution. The Trenton limestone underlies the western part of the county, the Niagara formation the eastern part and the Cincinnati group the central part. The Trenton is well exposed in a narrow belt along the Ford and Escanaba rivers and widely exposed in the valley of Rapid River. In Garden Peninsula the Niagara limestone forms a series of high bluffs or an escarpment from Garden to the southern end of the peninsula. Limestone is also exposed at many places along the low eastern shore and in the interior of the peninsula. The Cincinnati group forms the prominent bluffs on the west side of the peninsula separating Little Bay de Noc and Big Bay de Noc.

Character. The exposures of the Trenton limestone are characteristically shaly or argillaceous, usually containing from 5 to 10 per cent of silica, iron, and alumina. The upper beds are generally dolomite but the lower ones are usually low magnesian limestone. As far as known all of the exposures of the Niagara belong to the Manistique series.

Though typically shale the Cincinnati group in Delta county also contains much argillaceous limestone and very calcareous shale.

Quarries and Localities.

John Bichler quarry, Groos. The Trenton limestone is exposed at various places along the lower course of the Escanaba River for a distance of about six miles. About four miles north of Escanaba, in the vicinity of Groos, limestone is exposed in the river channel and forms narrow benches on either side flanked by high hills of glacial drift. For a number of years John Bichler has been operating a quarry (Pl.

8 B) on the narrow bench on the west side of the river, chiefly for crushed stone and rough building block. The quarry consists of an upper and a lower bench. The maximum depth at the time of the writer's visit was about 23 feet. The depth of the upper portion was from 4 to 11 feet. Most of the limestone is bluish, argillaceous, and crystalline with thin wavy laminae and bands of blue and black shale and thin beds of very fossiliferous limestone. Some of the limestone is very thin bedded and some massively bedded. The more massive beds are used for rough building block but most of the stone is crushed for road making, concrete and ballast. Formerly the stone was burned locally for lime but it is said to burn hard and produce an inferior product. Analyses Nos. 247 and 248 are indicative of the argillaceous and low magnesian character of the beds. Analysis No. 249 by Rominger is from the highest exposed beds near the mouth of Escanaba River and shows that these, allowing for the impurities, are practically normal dolomite. The exposure from which Rominger obtained his sample is on the east bank of the river near the power plant and apparently almost directly across from Bichler's quarry. Analysis No. 250, also by Rominger, is from the "wedge-shaped" limestones directly below the dolomites. It is probable that these "wedge-shaped" limestones of Rominger belong to the group of low magnesian limestones exposed in Bichler's quarry.

According to Rominger* the "wedge-shaped" limestone series is underlain by very shaly and sandy dolomitic limestone containing over 20 per cent of silica. Analysis No. 251 by Rominger is from a ledge exposed in the river channel about six miles above its mouth.

The following test on the wearing quality of this stone was made by the Division of Tests, Office of Public Roads, U. S. Department of Agriculture, Washington, D. C., to determine its qualifications as a road material:

Specific gravity	2.80
Weight per cu. ft	175.00
Water absorbed per cu. ft	0.39
Per cent of wear	3.40
French co-efficient of wear	11.60
Hardness	16.50
Toughness	12.09
Cementing power	good

The sample was a "dolomite of average hardness, slightly above the average in resistance to wear for dolomite and with good cementing value. Suitable for use on medium traffic roads." L. W. Page, Nov. 2, 1906.

Masonville. Trenton limestone is exposed one mile southwest of Masonville along Day's River for a half mile or more. Many years

*C. Rominger, Vol. III, Pt. III, pp. 58, 59.

ago a small quarry located on the east bank of the river about 600 paces from the "Soo Line" railroad was operated for burning lime. The quarry consists of an excavation about 250 feet long, 150 feet wide and 6 feet in depth to the level of the water in the stream adjacent. The stone is buff to gray crystalline and fossiliferous limestone. Analysis No. 252 is typical in that it shows the usual argillaceous character of the Trenton limestones. According to local residents, the lime was gray, slow setting, i. e., hydraulic, and did not keep well.

Rapid River. Exposures of the Trenton limestone are almost continuous from the village of Rapid River northward for six or seven miles along the west side of the valley of the stream of the same name. The exposures are in the form of low ridges of no particular orientation, though those having a northeast-southwest direction apparently predominate. The exposures are buff to gray, crystalline, fossiliferous low magnesian limestone with an argillaceous content characteristic of the Trenton limestone, as shown by analysis No. 253. Analysis No. 254 by Rominger is from an exposure of coarsely crystalline dolomite of the Upper Trenton above the mill pond near the mouth of Whitefish River. According to Rominger* Whitefish River flows over ledges of similar dolomite and dolomitic limestone as far north as section 2, T. 43 N., R. 20 W. It is probable, however, that many of the more northerly exposures are low magnesian limestone rather than dolomite. The lower course of Whitefish River is largely through swamps and the exposures along the channel of the river are under very unfavorable quarrying conditions.

Bark River. Trenton limestone is exposed in the vicinity of Bark River and recently a quarry has been opened to supply crushed stone for local road building. Judging from hand samples the stone is similar in every way to the Trenton as exposed elsewhere in the county.

Garden Peninsula. As previously stated the Manistique series of the Niagara formation is exposed at many places on Garden Peninsula, especially along the west shore where it forms bluffs or cliffs from 10 to over 200 feet in height. Of the three most conspicuous bluffs, the most northerly is known as Garden Bluff, the central as Middle Bluff, and the most southerly as Burnt Bluff.

Middle Bluff. At Fayette the cliffs rise vertically to heights 70 to 90 feet above lake level. The upper receding portion carries the height probably to between 125 and 150 feet above the water. These cliffs are known as Middle Bluff. The old Jackson Furnace Co. was

*C. Rominger, Vol. I, Pt. III, pp. 62-64.

located here and used the limestone in smelting iron until the available supplies of wood were exhausted. The following section is exposed at the old quarry:

Section at Middle Bluff, Garden Peninsula.

		Feet.
	Surface	0–3 +
1.	Thin bedded densely crystalline dolomite	15 +
2.	Buff fossiliferous high magnesian limestone or dolomite with druse cavities. The line of separation between No. 1 and No. 2 was concealed by talus	4 +
3.	Very hard buff to gray thin bedded cherty dolomite	9
4.	Hard, thin-bedded, and very cherty dolomite. Many seams and nodules of chert or flint similar to the chert horizons at Manistique	10
5.	Hard light bluish densely crystalline dolomite	2
6.	Very massive, fossiliferous and high magnesian limestone, with wavy laminations and druse cavities. Weathered into nodular masses	16
7.	Bluish very thin bedded densely crystalline dolomite	8
8.	Buff massive, fossiliferous and high magnesian limestone, with druse cavities	5
9.	Hard buff massive dolomite with a parting of very thin bedded and densely crystalline dolomite in the center	6
10.	Coarsely crystalline dolomite with an irregular fracture and bluish mottlings distributed more or less parallel to the bedding	3
11.	Light colored, hard, very thin bedded, and densely crystalline dolomite. Breaks into very thin plates and weathers bluish	4
12.	Buff finely crystalline dolomite with a pronounced conchoidal fracture. This is the lowest bed exposed in the quarry	1
13.	Buff very massive, very fossiliferous (coral) and high magnesian limestone	5
14.	Bluish hard thin bedded and densely crystalline dolomite	4 –
15.	Alternating series of massive crystalline and densely crystalline layers of high magnesian limestone and dolomite. Weathers bluish	11
16.	Buff thin bedded densely crystalline and finely laminated dolomite	3 –
17.	Buff sandy appearing dolomite with dark buff and brown streaks, very brittle and breaks with a very pronounced but granular conchoidal fracture. A thin but extremely persistent bed easily traceable for a long distance along the lake shore	1
18.	Buff, massive, fossiliferous and high magnesian limestone with druse cavities	3 –
19.	Hard bluish, thin bedded, and densely crystalline dolomite	2
20.	Buff, massive high magnesian limestone with druse cavities	1
21.	Hard light buff thin bedded densely crystalline dolomite	1
22.	Buff massive, fossiliferous (coral), heavy magnesian limestone with druse cavities	5
23.	Hard crystalline and high magnesian limestone with bluish stripes. This ledge occurs beneath the water	3 +

Bed No. 12 is the lowest exposed at the quarry but owing to the gentle southeasterly dip of the strata beds Nos. 14 to 23 are brought above lake level at the north end of the bluff about a half mile north of the quarry.

At Fayette a reef of limestone 15 to 30 feet in height extends out into Big Bay de Noc in the shape of a fish hook, forming a small but very deep nearly landlocked harbor. The height and extent of the exposure and the presence of a natural harbor give exceptionally favorable conditions for development, but unfortunately the stone is not of the quality now demanded for general fluxing or chemical purposes. Many of the beds undoubtedly would burn easily and make very good mild lime. The finely crystalline beds, however, generally burn very hard.

Burnt Bluff. Burnt Bluff is on the lake shore about three miles southwest of Middle Bluff. This is the largest and highest of the bluffs. It rises about 235 feet above the water and extends along the shore for about two miles. In places it has a sheer face of 60 feet or more. The surface of the bluff gradually slopes southeastward in the

general direction of the dip of the strata and it is only lightly covered with drift, rock ledges being exposed at numerous places in the fields.

The strata are essentially buff to gray, crystalline to densely crystalline, heavy magnesian limestones and dolomites very similar to those of Middle Bluff at Fayette. The section as given by Rominger* is as follows:

Section at Burnt Bluff, Garden Peninsula.

		Feet.
1.	Siliceous (high magnesian) limestones with nodules of hornstone and many silicified but poorly preserved fossils. Top of hill	20–30
2.	Even-bedded (high magnesian) limestones. Top of the vertical cliffs	15–20
3.	Thick-bedded crystalline dolomite alternating with thin and unevenly bedded nodular limestones. Several of the layers contain silicified corals	20?
4.	Cellulose brecciated limestone with the rock fragments incrusted with yellow calc and dolomite spar	2
5.	Thick-bedded crystalline and fossiliferous dolomites containing spherical masses of Stromatopora and lenticular masses of snow white calc spar	10
6.	Thin-bedded dolomitic limestones with smooth conchoidal fracture	50

Analysis No. 254 by Rominger in 1873 was made from the lower 60 feet of Burnt Bluff and is indicative of the high magnesian character of these beds.

Near the south end of Burnt Bluff at Sac Bay bed No. 4, the cellulose, brecciated limestone 60 feet above the water at the north end of the bluff is at water level. The nominal dip is apparently 40 to 50 feet per mile to the south-southeast hence the dip along the strike of the beds is due to local undulations, which may be observed at many places in the Niagara in the Northern Peninsula. Cliffs of similar limestone also form most of the shore of Summer island at the south end of Garden Peninsula.

Garden Bluff. This bluff is at the entrance to Garden Bay about four miles north of Middle Bluff. Vertical cliffs of limestone, 20 to 40 feet in height, occur along the shore for a mile or more. The exposed beds are buff to gray crystalline to densely crystalline, high magnesian limestones and dolomites very similar to those at Middle and Burnt bluffs.

Point Detour. This locality was not visited by the writer but according to Rominger† the cliffs at Point Detour are about 8 feet high and are composed of the same massive beds of crystalline dolomite which forms Seoul Choix and Epoufette points. Crystalline dolomite of the Engadine member of the Upper Niagara is typically exposed on Seoul Choix Point, therefore it should occur at Point Detour and probably at other places on the eastern shore of Garden Peninsula, if Rominger's correlation is correct.

*C. Rominger. Vol. I, Pt. III, p. 47, 1869-1873.
†C. Rominger, Vol. I, Pt. III, p. 46, 1869-1873.

Rominger considered the massive dolomite at Detour and Seoul Choix points as lying below the fossiliferous beds on the higher western portion of Garden Peninsula, but it is unquestionably on top of them instead of below them.

Stonington. The bluffs in the vicinity of Stonington on the east side of Little Bay de Noc are formed of strata belonging to the Cincinnati series of shales, which at this place are very calcareous as shown by the following partial analyses made by Prof. G. A. Koenig of the Michigan College of Mines:

Analyses of beds near Stonington.

Analysis number.	Number of sample.	Per cent $CaCO_3$.	Thickness of bed in inches.
255	1	42.4	....
256	2	50.4	....
257	3	63.3	30
258	4	52.8	....
259	5	40.0	19
260	6	50.8	....
261	7a	57.3	4
262	7b	46.0	....
263	8a	49.6	6
264	8b	49.6	....
265	8c	51.6	5 spotted
266	9	66.4	5 spotted
267	10	42.4	3
268	11	45.2	6
269	12a	50.4	10
270	12b	43.2	....
271	13	44.0	6
272	14	54.0	8
273	15a	42.0	13
274	15b	44.0	....
275	16a	42.0	....
276	16b	43.6	30
277	16c	40.0	....
278	16d	40.0	....
279	17	34.0	7
280	18	36.0	30
281	18	32.0	....

It is possible that these argillaceous limestones and calcareous shales may be adapted for the manufacture of cement though the variable composition would require careful mixing in order to produce a uniform product.

Alton Postoffice. Extremely fossiliferous limestone is exposed in a bluff 70 to 80 feet in height along a small stream one and a half miles west of Alton, section 10, T. 40 N., R. 21 W. Black bituminous shale with thin and extremely fossiliferous beds of limestone is exposed in the creek bed. The soil is filled with masses of Stromatopora; a stone

fence 10 to 15 feet wide and several feet high is composed chiefly of masses of fossils. These fossiliferous beds apparently belong to the Cincinnatti group. The siliceous character of the upper beds and the shaly character of the lower ones make them of little or no commercial importance.

Summary. The extensive exposures of Trenton limestone in the western part of the county are chiefly of very argillaceous low magnesian character; the upper beds in some of the exposures are argillaceous dolomite. The limestone is unsuitable for most purposes, excepting crushed stone for road making, concrete, and railway ballast.

The very large exposures of the Manistique series of the Niagara formation are all heavily magnesian limestones and dolomites. Some of the beds burn easily and make very good mild lime. Other beds are burned with difficulty. As a whole the beds are more impure than those of the overlying Engadine dolomite, hence are less satisfactory for paper manufacture, or for use as a basic lining in open hearth furnaces. Their generally hard and resistent character make them suitable for road metal, concrete, and railroad ballast. In brief, the limestone resources of Delta county, though of great extent, are unimportant as compared with Schoolcraft and Mackinac counties.

Eaton County.

Distribution. The Bayport limestone occupies a narrow belt along the west side of Eaton county but it is exposed only at Bellevue. The area of limestone under light drift cover is probably not above 200 acres. It lies along the south side of Battle Creek just southwest of the village. The exposures are in the form of low bluffs, but limestone is said to occur beneath the low level bench along the creek. The limestone is relatively thin and in many places it has been completely removed by erosion.

Quarries.

Bellevue. At a very early date small quarries were opened for burning lime at Bellevue. Due to the exhaustion of wood fuel these were abandoned many years ago. At present the Burt Portland Cement Co. is operating a quarry and using the limestone and underlying shale in the manufacture of cement. The following is a more or less generalized section by Rominger* of the beds as formerly exposed in the old quarries now more or less filled with debris:

*C. Rominger, Vol. III, Pt. I, pp. 112-114.

Section in old quarries at Bellevue.

		Thickness, feet.
1.	Light colored thin-bedded limestone. (Present only on the highest rock elevations)	1
2.	Brown ferruginous dolomite either in continuous layers wedging out at both ends or in seams of irregular shaped septaria surrounded by calcareous shale.. (Present only on the higher rock elevations)	1
3.	Light colored (high calcium) limestones with smooth, conchoidal fracture in beds of variable thickness	3–4
4.	Brown ferruginous dolomite ($MgCO_3$, 23 per cent) with a dull earthy fracture	2
5.	Light colored limestone ($CaCO_3$, 96 per cent) with a smooth conchoidal fracture in beds of variable thickness, interlaminated with concretionary seams of limestone (chert or flint); fossils not generally abundant, but certain seams are crowded with them over widely extended areas	8–10
6.	Greenish white calcareous sandstone (SiO_2, 69 per cent; $CaCO_3$, 30 per cent) grading upward into pure limestone but with occasional thin seams of quartz sand. Locally this strata is brecciated. (Disconformity between the Bayport and the Michigan series below	

The section exposed in the Burt Portland Cement Co. quarry is as follows:

Section in the Burt Portland Cement Co. quarry, Bellevue.

		Thickness, feet.
	Surface	2–3
1.	White, light gray, and yellowish gray high calcium ($CaCO_3$, 94.78 per cent) limestone with a smooth conchoidal fracture and containing pockets and seams of yellow ferruginous sand and red clay. In one part of the quarry this bed contains a thin lens of gray sandstone	12
2.	Blue and green argillaceous (Al_2O_3, 4.04 per cent) limestone of variable thickness and with a breccia of limestone and sandstone. This represents the disconformity between the Bayport limestone and the Michigan Series	1–4
3.	Soft greenish blue calcareous (CaO, 13.45 per cent) shale or clay	2+

The limestone and shale are blasted down together, and loaded by steam shovel into tram cars which are hauled by steam power to the crushers. The occurrence of the shale and limestone together is a great advantage in the manufacture of cement. A part of the necessary mixing of the shale and limestone is done in the quarry; about ten parts of the upper white limestone is taken to one of the blue shale and argillaceous limestone beneath.

Analysis No. 282, made from a representative set of samples from the high calcium bed in the Burt quarry, and also analyses Nos. 283 to 286 are indicative of its average composition. Analysis No. 287 by Rominger is of the brown, ferruginous, magnesian limestone locally present in the vicinity of Bellevue.

Most of the area of quarryable limestone in the vicinity of Bellevue is owned by the Burt Portland Cement Co., but A. J. Zipp of Bay Shore has a deposit about a mile southwest of Bellevue on the south side of the Grand Trunk railroad. Formerly a quarry was operated in this deposit for burning lime and plans are reported to be under way to reopen the quarry for crushed stone products and for ground limestone for agricultural purposes. The hardness and general purity of the limestone makes it very suitable for such purposes. Quarrying conditions and shipping facilities are favorable.

Summary. The limestone deposits of Eaton county though of insignificant size in comparison with those of other counties in the northern part of the state are of very considerable economic importance on account of their high calcium character and the absence of other deposits of commercial size and similar grade in central and western Michigan.

Emmet County.

Distribution. The Dundee limestone underlies the extreme northern part of the county but, so far as the writer is aware, it is not exposed. The Traverse formation occupies the remainder of the county with the exception of a narrow belt across the western part underlain by the Antrim black shale. The Traverse limestone is exposed in a double line of bluffs or lake terraces on the south side of Little Traverse Bay from Kegomic westward into Charlevoix county. The principal exposures are along the lower bluff close to the water's edge. This bluff apparently averages between 40 and 50 feet in height. The upper terrace is of similar height but in places, owing to the uneven surface of both the rock and the glacial deposits, it is considerably higher. Due to surface deposits there are but few exposures along the upper bluff.

Quarries and Localities.

Kegomic. Formerly a quarry was operated at Kegomic in the SE. ¼ SW. ¼ section 27, T. 35 N., R. 5 W. The writer did not visit this quarry but the following is a section from a description and a set of samples furnished by Mr. W. E. Smith of Cadillac, Michigan:

	Thickness, feet.	Inches.
Dark gray crystalline and argillaceous limestone	2	....
"Rotten" shale	2	6
Dark bituminous crystalline and very fossiliferous (brachiopods) limestone	0	10
Blue shale	2	....
Buff and gray coarsely crystalline limestone	2 ±	....
Gray and buff very fossiliferous coarsely crystalline (brachiopods) limestone	2+	....

Petoskey. At Petoskey the lower terrace is between 40 and 50 feet in height and varies in width from a few hundred feet to a quarter of a mile or more. The upper terrace is nearly as high but, owing to the irregular surface of the glacial drift at the top, it is much more variable in height.

Northern Lime Co. quarries. In the eastern part of the city the Northern Lime Co. operate three closely connected quarries in the

lower terrace close to the lake shore for burning lime. Only a narrow strip is available for quarrying, due to the encroachment of buildings. The following is a section of Quarry C located farthest west:

Section in Quarry C.

		Thickness, feet.
	Sand	4–6
1.	Dark friable "sandy" magnesian limestone. Not used	6
2.	Very white earthy magnesian limestone. Burns black; not usable	2½
3.	White friable magnesian limestone. Usable but not of very good quality	3
4.	Gray earthy limestone with bands and mottlings of lithographic limestone. Beds apparently much alike but becoming less magnesian toward the bottom ($MgCO_3$, 16.30 per cent)	22
5.	Buff porous friable and extremely coralline limestone. Floor of quarry	1
6.	Dark earthy "magnesia" stone	1
7.	Gray to very light gray lithographic to dense grained high calcium limestone ($CaCO_3$, 96.36 per cent) with bituminous streaks. Smells strongly of bitumen when struck with the hammer. Thickness to lake level	8

In Quarry B, only about 250 paces east of C, the section is considerably different.

Section in Quarry B.

		Thickness, feet.
	Surface	3–6 +
1.	Mass of white Stromatopora and coral in a matrix of buff friable sugary magnesian limestone. Burned for common lime. ($MgCO_3$, 36.41 per cent)	15–20
2.	Buff semi-crystalline limestone with dark crystalline streaks	5
3.	Dark, brittle and laminated limestone. Breaks up into a fine mass when blasted	2
4.	Bluish dense grained limestone. Very good quality	3
5.	"Sandy" limestone. Poor quality	3
6.	Densely crystalline to earthy limestone. Burned for chemical lime ($CaCO_3$, 94.78 per cent)	7 –
7.	Laminated limestone with dark bituminous streaks	3
8.	Buff, soft, and very porous coralline limestone. Too soft for lime; left for floor of quarry	1 +

Quarry A, a short distance farther east, was not in operation but the beds are more or less similar in character and composition to those of quarry B.

The beds in the upper part of all three quarries are more or less completely dolomitized, but in general the magnesia decreases downward though not regularly. The beds near lake level are very pure high calcium limestone. This is illustrated by the following partial analyses of the stone in Quarry C from the top downward:

Quarry C.

Analysis of beds from top down.

Number analysis.	Number of bed.	$CaCO_3$.	CaO.	$MgCO_3$.	MgO.
288	1	69.04	38.66	30.85	14.75
289	2	66.88	37.45	32.23	15.41
290	3	92.36	51.72	6.92	3.31
291	4	89.50	50.12	8.05	3.84
292	5	90.96	50.94	5.65	2.70
293	6	89.04	49.86	9.47	4.53
294	7	97.36	54.52	1.69	.81

A. H. Koch, Michigan College of Mines, Sept. 20, 1913.

The same general decrease downward is also shown by analyses Nos. 295 to 197. In Quarry B, however, the magnesia increases slightly nearly to the bottom of the quarry where it suddenly drops to less than 2 per cent.

Quarry B.

Analysis of beds at east end of quarry from top down.

Number analysis.	Number of bed.	$CaCO_3$.	CaO.	$MgCO_3$.	MgO.
298	1	89.00	49.84	8.93	4.27
299	2	88.04	49.30	10.56	5.05
300	3	87.64	49.08	10.50	5.02
301	4	84.82	47.50	13.24	6.33
302	5	94.57	52.96	3.99	1.91

Analysis No. 303 was made from a representative set of samples from the lower 22 feet (bed No. 4) of gray earthy limestone in Quarry C. This analysis and also Nos. 293 to 297 show the magnesian character of the stone in the lower part of the quarry and also the low content of siliceous and argillaceous impurities. Analysis No. 304 is from the high calcium lithographic beds exposed in a test pit in the bottom of Quarry C. These beds are very pure but are not used for lime on account of their tendency to ''pop'' or break to pieces in the kiln, thus clogging the draft. Analysis No. 305 made from samples from all of the beds in Quarry B except No. 5 gave 16.30 per cent of magnesian carbonate. Analysis No. 306 shows the high calcium character of bed No. 7, which is sorted out for burning chemical lime. The top coralline and stromatoporoid bed, according to analysis No. 307, is a high magnesian limestone. The analyses in general indicate that the composition of the beds is variable horizontally as well as vertically. Analysis No. 308 is apparently from the dark lithographic beds near lake level, No. 309 from the upper beds of the quarry, and No. 310 from the lower beds. Owing to the variable character and composition of the beds hand sorting is necessary. The company burns a large amount of both commercial and chemical lime, and also grind limestone for agricultural purposes. Owing to the soft friable character of the stone it is unsuitable for crushed stone purposes.

Antrim Lime Co. quarry. The quarry of the Antrim Lime Co. is the only one operating in the upper terrace in the vicinity of Petoskey. The floor of the quarry is said to be 85 feet above lake level, or about 40 feet above the highest beds exposed in the lower bluff. Since the section in the quarry has a maximum thickness of about 25 feet, the top

of the highest exposed ledge in the vicinity of Petoskey is apparently about 110 feet above lake level. The overburden, largely of sand, is becoming very thick, averaging from 8 to 10 feet or more and the area of easily quarryable stone is apparently small. It is owing chiefly to the high average purity of much of the stone and its easy burning qualities that profitable operation is possible.

The following section is exposed in the quarry:

Section in Antrim Lime Co. quary.

		Thickness feet.
	Sand and gravel	8 +
1.	More or less broken ledges of light buff or white sugary limestone. Parting of shale at the base	3
2.	White earthy and very brittle limestone. Parting of black bituminous and laminated shale at the base	8
3.	White earthy limestone with darker laminations toward the base	7
4.	Buff porous earthy and coralline limestone	1 −
5.	Buff sugary and laminated limestone	2
6.	Buff dense grained limestone. Bottom bed quarried	1
7.	Dark buff limestone with numerous fine dark bituminous bands. Floor of quarry	1 +

The upper 12 feet of white earthy limestone contains (Anal. No. 311) over 97 per cent of calcium carbonate but the lower 12 feet of white and buff limestone contains (Anal. No. 212) over 11 per cent of magnesium carbonate, and is similar to the buff sugary limestones in the upper part of the lower bluff.

By a comparison of the sections in the different quarries it appears that in the vicinity of Petoskey there are an upper high calcium horizon as exposed in the Antrim Lime Co. quarry, a middle very thick (75 feet) magnesian horizon, and a lower darker colored high calcium one extending from just above lake level to an unknown depth below. These horizons appear to extend westward into Charlevoix County. The differences in the character of the stone in the different quarries in the lower bluff westward from Petoskey apparently is due largely to undulations along the strike of the beds. At one point the lower darker high calcium beds are elevated above lake level, forming the lower bluff, but at another they are depressed, bringing the upper yellow or buff magnesian horizon down to or even below lake level.

Petoskey Crushed Stone Co. quarry. There are numerous quarries along the lake shore westward from Petoskey but all are idle or abandoned except that of the Petoskey Crushed Stone Co., located about four miles west of Petoskey (S. E. ¼ Sec. 2, T. 35 N., R. 6 W.) This company has opened a large quarry (Pl. III B) in the lower terrace which at this point is a quarter of a mile in width. Most of the limestone is hard, crystalline, and high calcium in contrast to that in the Petoskey quarries. As a consequence it is largely disposed of for Portland cement, flux, road metal, concrete, ballast, etc., for which it is said to be very suitable. The uniformity in the character of the beds

permits the use of steam shovels and locomotives in handling the quarry product. There are two quarries separated by the Pere Marquette railroad, but only one is operated. In the larger northern quarry about 10 acres of stone had been quarried at the time of the writer's visit, to depths varying from 8 to 25 feet. A second bench had been started on the east side of the quarry at practically lake level. The maximum height of the two benches was about 40 feet.

The area of stone under light overburden in the vicinity of the quarry, though of uncertain extent, is considerable. On the west, however, the stone is cut out by a drift filled ravine.

The following is a more or less generalized section of the stone exposed near the east end of the quarry:

Section at east end of Petoskey Crushed Stone Co. quarry.

		Thickness, feet.
	Surface	0–3
1.	Coralline and Stromatoporoid limestone with a buff crystalline matrix	6
2.	Hard tough gray crystalline high calcium limestone	2 –
3.	Dark lithographic high calcium limestone adapted for sugar manufacture	3 –
4.	Hard tough gray crystalline high calcium limestone. Said to average above 90 per cent calcium carbonate. Lower ledges concealed by a heavy blast of stone	25 +

Analysis No. 313, from the upper 12 feet gave 93 per cent calcium carbonate and nearly 5 per cent of magnesium carbonate. The lower beds were concealed and representative samples could not be obtained.

W. E. Smith quarry. Immediately on the west of the property of the Petoskey Crushed Stone Co. in sections 9 and 10, T. 34 N., R. 6 W., W. E. Smith, et. al., own about 210 acres of limestone land of which about 150 acres is under light overburden. The property lies chiefly on the lower terrace which has a maximum width of about a third of a mile. At the edge of the terrace near the lake the rock surface is from about 15 to 35 feet above lake level, but it gradually rises away from the lake until at the base of the upper terrace it is from 65 to 75 feet above the lake.

Near the west end of the property the Petoskey Stone & Lime Co formerly operated a small quarry and lime kiln. The section exposed is as follows:

Section in W. E. Smith, et. al., quarry.

		Thickness, feet.	Inches.
	Surface. The quarry is located along a narrow high ridge of sand and gravel.	0–10	....
1.	Broken ledge of light buff gray magnesian ($MgCO_3$, 14.38 per cent) limestone	3–4	....
2.	Buff to dark buff gray crystalline limestone. Fossiliferous shale seam at the base	4	....
3.	Buff to dark buff gray crystalline limestone. Black shaly parting in the middle	2	....
4.	Black and extremely fossiliferous shale filled with brachiopods.	0	6
5.	Dark gray finely crystalline limestone	2	....
6.	Dark bituminous and fossiliferous shale	0	6
7.	Dark lithographic to finely crystalline limestone	3 ±	....
8.	Dark gray densely crystalline limestone with many large heads of Stromatopora and corals. Owing to the fossil masses the contact between No. 7 and No. 8 is very wavy	3 ±	....
9.	Dark lithographic and very brittle high calcium limestone	1	....
10.	Crystalline to dense grained fossiliferous (coral, brachiopods) limestone. Bottom bed quarried	1 −	....
11.	Dark lithographic brittle high calcium limestone. The base of the bed is concealed. Average analyses of beds Nos. 2, 3, 5, 7-11 inclusive gave 93.96 per cent $CaCO_3$	2 +	....
12.	Gray earthy to crystalline thin bedded magnesian ($MgCO_3$, 14.84 per cent) limestone	1	....
13.	Fine grained earthy magnesian ($MgCO_3$, 14.84 per cent) limestone. Exposed at the foot of the trestle	3	....
14.	Next lower beds concealed by talus but at a little distance lakeward from the quarry dark lithographic and dark gray crystalline limestones are exposed in low ledges just above lake level	?	....

Beds Nos. 1, 12, and 13 contain (Anal. Nos. 314 and 316) between 14 and 15 per cent of magnesium carbonate, but beds Nos. 2, 3, 5, 7-11 inclusive contain (Anal. No. 315) nearly 94 per cent of ~~magnesium~~ calcium carbonate.

Similar beds are exposed along a dry run a short distance to the southeast and also in a test pit 6 feet deep on the east end of the property as shown by the following section:

Section in Test Pit near S. ¼ post of sec. 3, T. 35 N., R. 6 W.

		Thickness, feet.
	Surface	2
1.	Dark lithographic high calcium limestone with corals and brachiopods in lower part. This shale seam at base of the bed	2
2.	Hard light gray dense grained limestone	2
3.	Dark crystalline and fossiliferous (corals and brachiopods) limestone. Bottom of pit filled with rubble	1 +

An analysis (No. 317) of a composite of samples taken about one foot apart in the test pit gave nearly 95 per cent of calcium carbonate and only about 2 per cent of magnesium carbonate.

It is to be noted that none of the white and buff sugary limestones quarried at Petoskey appear to be present on this property or in the quarry of the Petoskey Crushed Stone Co., and that the dark lithographic and gray crystalline beds are similar to those exposed near

lake level in the test pit in the bottom of Quarry C of the Northern Lime Co. at Petoskey. Westward from Petoskey, due to an undulation, this series is brought above lake level and forms all of the lower terrace for a considerable distance in sections 1, 2, and 10, T. 34 N., R. 6 W.

The W. E. Smith property apparently contains the largest area of easily quarryable limestone in the vicinity of Petoskey. From lake level to bed No. 1 in the old quarry the stone is chiefly high calcium. Higher beds are exposed in a gulley southeast of the quarry and they are similar in general appearance and probably in composition to the lower beds. The highest beds, probably 25 to 30 feet in thickness, occur in front of the upper terrace but are not exposed and little is known of their physical or chemical characteristics.

Bell quarry. About one-half mile west of the W. E. Smith property (N. ½ N. ½ sec. 9, T. 34 N., R. 6 W.) there is an old quarry and kiln, known locally as the Bell quarry and formerly operated by the Elk Cement & Lime Co. It fronts directly on Little Traverse Bay and is composed of an upper and a lower portion. The working face in the upper is about 25 feet and the lower about 20 feet. The section is as follows:

Section in Bell quarry.

		Thickness, feet.
	Surface	1–3 +
1.	Dense grained gray limestone	5
2.	Weathered blue and very fossiliferous shale containing an abundance of brachiopods and crystals of gypsum. Talus concealed the lower portion of the shale but its thickness is said to be about	6
3.	Dark gray to buff gray crystalline to dense grained fossiliferous limestone with cup corals and heads of Stromatopora and Acervularia and other corals. Bottom of bed concealed by talus. Floor of upper quarry	13 ±
4.	Dark gray dense grained to finely crystalline and fossiliferous limestone, containing cup corals, heads of Acervularia, and brachiopods	2
5.	Dark buff gray lithographic limestone containing disseminated calcite crystals and with heads of Acervularia and Stromatopora at the bottom	2
6.	Dense grained buff dark gray limestone with mottlings and with a black bituminous fossiliferous phase at the top and a shale parting at the bottom	4½
7.	Dark bituminous and lithographic limestone with a few corals. Black bituminous shale parting at the bottom	3
8.	Dark bituminous lithographic limestone with a black bituminous shale parting at the bottom	1
9.	Light gray lithographic limestone with a very thin shale parting at the bottom	1
10.	Gray to buff dense grained to crystalline and fossiliferous (brachiopods) limestone with a lithographic texture and a thin shale parting at the base	2
11.	Gray to buff limestone, lithographic near the top and crystalline and fossiliferous near the bottom. Bottom of the exposed portion of this bed is practically at lake level	3 +

No analyses of the stone in this quarry are available but according to persons acquainted with the quarry most of the stone is high calcium, especially the lithographic stone of the lower bench. The dark gray crystalline or lithographic character of the beds indicates that they are to be correlated with similar beds occurring near water level at Petoskey. Toward the west, however, the strata descend so that at Bay Shore, Charlevoix county, about two miles distant, the upper buff to yellow, friable limestone of the Petoskey section extends below

the level of the bay. The last exposure of the dark lithographic beds according to Rominger's description is apparently about one mile east of Bay Shore and consists of two ledges extending from water level to 6 or 8 feet above. The stone as analyzed (Anal. No. 174) by him contains 98 per cent of calcium carbonate.

Summary. The limestone resources of Emmet county are of relatively small extent, being confined chiefly to narrow terraces along the shore of Little Traverse Bay. The total thickness of the section exposed along the lake shore is apparently about 135 feet.

The upper white earthy limestones 15 to 20 feet in thickness are high calcium, the middle buff to gray sugary limestones about 75 feet in thickness range in composition from low to high magnesian, and the lower dark crystalline to lithographic limestones 40 feet or more in thickness are largely high calcium. In the vicinity of Petoskey, the middle magnesian portion forms all of the lower and the base of the upper terrace. Westward the dark crystalline and lithographic beds exposed near the level of the bay at Petoskey, gradually rise and, four or five miles west of the city, form most of the lower terrace. Farther west they descend until at Bay Shore they are below lake level. The three different horizons and the undulations of the beds along the lake shore are very vital factors in determining the commercial possibilities of deposits in Emmet county.

Huron County.

Distribution. The Bayport limestone forms several relatively small areas in the western part of Huron county and is exposed or near the surface in two oval shaped areas (fig. 13) southeast of Bayport and on some of the islands in Saginaw Bay. One of the ovals extends southeast from Bayport for about three miles into the eastern part of section 5, T. 16 N., R. 10 E. The other extends from the southeastern part of section 8 southeast into the northwestern part of sec. 15, T. 16 N., R. 10 E., a distance of about two miles. The ovals, especially the larger, are marked on the northeast side by a prominent ridge and low bluffs.

Quarries and Localities.

Bayport quarry. This quarry (Pl. IV A) though commonly referred to as the Bayport quarry, is located about three miles southeast of Bayport in section 5, T. 16 N., R. 10 E., and near the southeast end of the larger oval. It is a large quarry operated by the Wallace Stone Co. chiefly for crushed stone, the general hardness and toughness of the stone adapting it for road metal, concrete and ballast. The quarry,

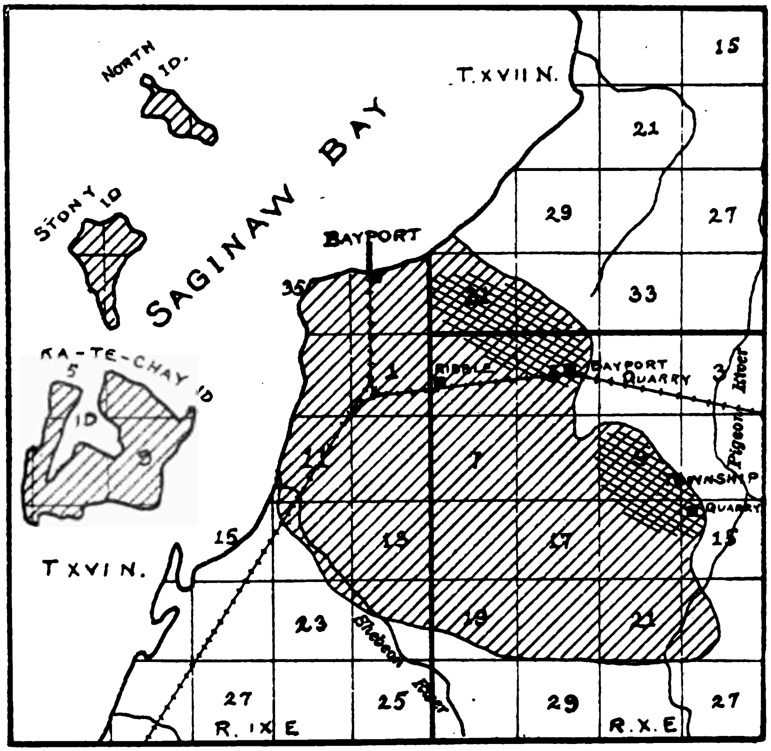


Figure 13. Map showing distribution of the Bayport limestone in the vicinity of Bayport, Huron county. Double hachured areas indicate thinly drift covered areas.

which has been in operation for over thirty years, consists of two openings, 8 to 12 feet in depth and with a combined area of over 80 acres. This, however, is only a small fraction of the area of easily quarryable stone remaining. The section below was exposed in the quarry:

Section in Bayport quarry.

		Thickness, feet.
	Surface	½–2
1.	Thin bedded fossiliferous limestone. Locally weathered to a soft yellowish mass at the top. Hard and sandy near the bottom. Mass of corals in lower part of bed	3
2.	Hard gray dense grained magnesian limestone with a thin sandy layer near the bottom. Upper and lower part suitable for lime but hand sorting is necessary. Chert nodules numerous in upper portion of the bed	3½
3.	Hard gray dense grained to crystalline sandy and magnesian limestone. Samples apparently from No. 2 and No. 3 together gave 14.5 per cent $MgCO_3$ and 20.85 per cent SiO_2	3
4.	Black bituminous and shaly limestone locally called "Black shale"	0½
5.	Dark gray lithographic limestone with a smooth conchoidal fracture. Formerly used for building stone	1 —

Formerly there was an upper high calcium layer which was burned for lime but this bed, according to Mr. R. N. Wallace, manager of the Wallace Stone Co., has disappeared with the progress of quarrying.

Most of the lower beds are sandy or cherty and magnesian and this unfits them for lime burning or for fluxing and chemical purposes. Except where locally weathered at the surface the stone is hard and, being situated in the broad flat belt of lake clays of eastern Michigan, almost wholly lacking in suitable road or concrete materials, it is used extensively for road building and concrete. The section below the floor of the quarry is composed largely of very sandy limestones and calcareous sandstones.

An analysis, (No. 318) from the upper high calcium bed formerly present, gave over 91.5 per cent of calcium carbonate and shows that it was similar in composition to the Bayport limestone in Arenac (see analyses Nos. 141-144) county on the western side of Saginaw Bay. Analysis No. 319 is indicative of the sandy and magnesian character of the lower beds.

The following tests were made by the Office of Public Roads, U. S. Department of Agriculture, Washington, D. C.:

Number of test.	Rock.	Weight lbs. per cu. ft.	Absorption lbs. per cu. ft.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
1287.......	Limestone	165	1.34	2.7	14.8	15.1	12	49
1288.......	Dolomitic limestone	165	1.35	....	....	15.3	12	50
4063.......	Limestone	165	1.60	3.3	12.0	15.4	11	48

A test* made at the Water Town Arsenal by Capt. Butler gave a crushing strength of 26 110 lbs. This is very high for limestone. The specimen tested was 2.61 inches thick with a compression surface of 29.65 square inches.

A quarry has been opened near the southeast end of the smaller oval in the N. W. ¼ sec. 15, T. 16 N., R. 10 E., Windsor Township, for road material. At the time of the writer's visit the quarry was about 150 feet in length and 8 to 10 feet in depth. The area of stone under light cover is apparently two to three hundred acres. The beds exposed were very similar to those of the Wallace or Bayport quarry as may be seen from the following section:

		Thickness, feet.
	Surface..	1–2 +
1.	Hard grayish buff fine grained limestone with numerous cup corals at top and bottom..	4
2.	Hard grayish buff dense grained to finely crystalline limestone with some chert nodules. Suitable for lime. According to Mr. R. N. Wallace, Manager of the Wallace Stone Co., this bed contains about 65 per cent of $CaCO_3$........	3
3.	Black bituminous shaly limestone "Black shell"........................	0.6 in.
4.	Hard light gray dense grained to finely crystalline limestone with many small crystals of pyrite..	2

*A. C. Lane, Geology of Huron County, Vol. VII, Pt. II, 1900, p. 215.

Charity Islands. The Bayport limestone is exposed on Charity Islands, North, and Stony (or Heistermann) islands and according to Winchell's*, Rominger's†, and Lane's‡ descriptions the exposures are in the form of low ledges near the water level and the beds, characteristic of the Bayport, are sandy or cherty or are replaced by sandstone. On North Island a small quarry was formerly operated many years ago. The beds are cherty and very fossiliferous.

Summary. The limestone resources of Huron county are confined largely to a ridge extending southeast from Bayport for five or six miles. Quarrying conditions are most favorable in the oval areas, one at the northeast end of the ridge and the other at the southeast end. The thickness of the commercial stone is small, being generally from 8 to 16 feet. Most of the stone is hard, siliceous, and magnesian and is chiefly adapted for road making, concrete, and railroad ballast. Owing to their location in a region largely devoid of other suitable material for such purposes, the deposits are of large local importance.

Jackson County.

Distribution. The Bayport limestone is present largely as a capping on the tops of pre-Coal Measure hills. The deposits are generally very thin and small. The coal deposits more or less completely fill up the valleys between the hills and lap upon the edges of the Bayport limestone. During the Pleistocene, portions of the hills were dislodged, carried away by the ice, and buried in the glacial debris. According to Rominger§ there are many of these large masses of Bayport limestone, with attached portions of the underlying shaly Michigan series, more or less completely buried in the drift in Jackson county. These masses simulate exposures of the rock in place but generally the uptilted position of the beds betray their character.

As in Arenac, Eaton, and Huron counties, the Bayport limestone is generally cherty, sandy, or magnesian and the proportion of high calcium stone in the formation is small.

Quarries and Localities.

Formerly many small quarries were operated in Jackson county for burning lime but these, due to the exhaustion of suitable wood or to the siliceous character of the beds, have been abandoned for many years. Some of the quarries are being reopened for road material.

*A. Winchell, First Biennial Report, 1860, p. 102.
†C. Rominger, Vol. III, 1873-1876, p. 119.
‡A. C. Lane, Vol. VII, Pt. II, 1900, p. 105.
§C. Rominger, Vol. III, Pt. I, 1873-1876, p. 114.

Parma. About a mile northeast of Parma in sections 29 and 30, T. 2 S., R. 3 W., the Bayport limestone* underlies an area of probably about 300 acres. Several quarries were once operated in this deposit. The upper bed† is a brown ferruginous dolomite and the lower a dark, bluish, high calcium limestone full of sparry and siliceous veins. The upper bed contains (Anal. No. 320) about 18 per cent of iron and alumina and 11 per cent of magnesium carbonate, the lower bed from nearly 3 to 14 per cent of silica (Anal. Nos. 321-2).

South of Parma in Spring Arbor township (T. 3 S., R. 2 W.) there are many small exposures of Bayport limestone. A quarry was operated in section 17 in the early 30's for burning lime. The upper bed in the old quarry, as at Parma and Bellevue, is a brown ferruginous magnesian limestone. The lower bed 8 to 10 feet in thickness is high calcium limestone. Analysis No. 323 is from a small exposure of high calcium limestone along the road in section 11 or 12 of this township. Analysis No. 324 is from a small exposure of dolomite, probably the upper bed, on the road between sections 24 and 25. Analysis No. 325 is of another small exposure of high calcium limestone, the location of which is given by Rominger as "three miles south of Jackson on Mr. Shoemaker's farm." At this place the high calcium bed is overlain by 4 or 5 feet of brown ferruginous dolomite. All of the above exposures are directly underlain by green sandy shales and sandstones of the Michigan series. Analysis No. 326 is from a mass of drift limestone in a railroad cut about 3 miles south of Jackson on the Cincinnati and Northern Railroad.

Portage River. A prominent east and west ridge of Bayport limestone occurs about four miles north of Jackson on the north side of Portage River in sections 1 and 2, T. 2 S., R. 1 W., and section 6, T. 1 S., R. 1 E. The limestone forms a more or less continuous capping along the top of the ridge for more than a mile. Several small quarries were formerly operated in this ridge. On the east side of section 2, T. 2 S., R. 1 W., an old quarry has been reopened for road material. The upper four or five feet in the quarry is a light gray dense grained high calcium limestone. This is underlain by a conglomerate of limestone and sandstone pebbles and boulders in a matrix of green sandy shale. This undoubtedly represents the disconformable contact between the Bayport limestone and the Michigan series. From 8 to 10 feet of light gray, dense grained, high calcium limestone similar to that at Bellevue, Eaton County, is exposed in an old quarry in the SE. ¼ SW. ¼ section 1, T. 2 S., R. 1 W., five to six feet in another quarry in the NE. ¼ SE. ¼ of the same section, and about seven feet in a third

*C. Rominger, Vol. III, Pt. I, 1873-1876, pp. 114, 115.
†C. Rominger, Vol. III, Pt. I, 1873-1876, pp. 114, 115.

quarry in the NW. ¼ SW. ¼ section 6, T. 2 S., R. 1 E. This limestone contains (Anal. Nos. 327-332) from about 92 to 97 per cent of calcium carbonate, 1.25 to 2.80 of silica and but very little magnesium carbonate.

Summary. Jackson county contains numerous small areas of Bayport limestone which generally caps hills and ridges. The high calcium beds are thin, more or less sandy and cherty, and are associated with ferruginous dolomite or sandy green shale. The resources are of little economic value except as a source of road material, concrete, etc., for local use.

Kent County.

Distribution. The Bayport limestone and the Michigan series underlie a large portion of Kent county but the formations are deeply buried under glacial drift except along the valley of Grand River from Grand Rapids to Grandville. Formerly the Bayport limestone was exposed along the river banks in Grand Rapids but now most of the exposures are concealed by dams and buildings.

Luce County.

Distribution. The Trenton limestone, the Beekmantown (Calciferous), and the Niagara formations occupy parallel belts across the southern part of Luce county. Exposures of the first two are few and unimportant. The Niagara is exposed along a high bluff extending through the extreme southern part of the county in section 31, T. 45 N., R. 8 W., and section 36, T. 45 N., R. 9 W.

D. N. McLeod Lumber Co. quarry. At the time of the writer's visit (1913) a railroad spur along the base of the bluff was under construction preliminary to the opening of a quarry. The bluff, apparently 80 to 100 feet in height, is about a half mile north of Hendricks quarry and is composed of similar beds. (See Hendricks quarry, Mackinac county). The upper portion of the bluff is formed by the Fiborn limestone, which on the weathered surfaces shows the presence of numerous fossils. The lower part of the bluff is largely concealed by talus but the beds belong to the Hendricks series.

A number of core drillings were made by the Union Carbide Co. of Sault Ste. Marie in section 36, T. 45 N., R. 9 W., and also in the sections adjoining on the south. The analyses of the core from the deepest hole in section 36 is given below:

Test Hole North of Hendrick's Quarry.

Analysis of Drill Core SE. ¼ sec. 36, T. 45 N., R. 9 W., Luce County. Analysis furnished by Joseph Scales, Supt. Union Carbide Co., Sault Ste. Marie, Mich.

Analysis No.	Sample No.	Core.		Silica. SiO_2. %	Iron-Alumina. Fe_2O_3-Al_2O_3. %	Calcium carbonate. $CaCO_3$. %	Calcium oxide. CaO. %	Magnesium carbonate. $MgCO_3$. %	Magnesium oxide. MgO. %	Carbon de-oxide and water. CO_2-H_2O. %	Remarks.
		Thickness, feet.	Depth, feet.								
334	1	1'- 8"	5'- 8"	1.51	0.25	*93.07*	52.08	*1.40*	0.68	45.48	Fiborn Limestone.
335	2	6'- 0"	11'- 8"	1.96	0.23	*94.71*	53.08	*1.55*	0.74	43.99	Bed No. 3 of section in Hendricks quarry.
336	3	2'-10"	14'- 6"	0.78	0.19	*96.84*	54.27	*1.23*	0.59	44.17	
337	4	4'- 3"	18'- 9"	0.52	0.35	*95.94*	53.77	*1.34*	0.64	44.72	Upper part of bed No. 4?
338	5	2'- 0"	20'- 9"	1.14	0.32	*96.72*	54.21	*1.44*	0.69	43.64	
339	6	6'- 9"	27'- 6"	2.59	0.23	*91.18*	51.10	*4.16*	1.99	44.09	Lower part of bed No. 4?
340	7	6'- 3"	33'- 9"	1.78	0.41	*89.06*	49.91	*8.72*	4.17	43.73	
341	8	4'- 3"	38'- 0"	3.79	0.76	*69.20*	38.78	*21.44*	11.69	45.08	Compare beds Nos. 4 to 9 in test pit in bottom of quarry.
342	9	3'-10"	41'-10"	1.28	0.45	*79.03*	44.29	*22.40*	10.16	43.82	
343	10	3'- 2"	45'- 0"	1.11	0.17	*89.52*	50.17	*8.86*	4.24	44.31	
344	11	3'- 6"	48'- 6"	0.90	0.34	*91.60*	51.34	*7.65*	3.66	43.76	
345	12	6'- 0"	54'- 6"	5.57	0.25	*86.43*	48.44	*2.03*	0.97	44.77	
346	13	8'- 0"	62'- 6"	1.82	0.21	*92.62*	51.91	*2.72*	1.30	44.76	Lower high calcium horizon.
347	14	7'- 3"	69'- 6"	0.49	0.14	*97.26*	54.51	*1.07*	0.51	44.45	
348	15	5'-11"	75'- 8"	0.93	0.19	*91.02*	51.01	*7.34*	3.51	44.36	
349	16	5'- 4"	81'- 0"	1.47	0.23	*80.42*	45.07	*18.84*	9.01	44.22	
350	17	12'- 8"	93'- 8"	6.76	1.55	*62.40*	34.97	*26.95*	12.89	43.83	
351	18	9'-10"	103'- 6"	2.68	0.37	*80.42*	45.07	*14.36*	6.87	45.01	

Note.—Numbers in italics are calculated from original analyses.

Summary Analysis Covering Limestone Deposit in Township 45, Sec. 36, N. Range 9 West.*

Laboratory Union Carbide Co., Sault Ste. Marie, Mich.

Number of analysis.	Sample number.	SiO_2. %	$Fe_2O_3+Al_2O_3$. %	$CaCO_3$. %	CaO. %	$MgCO_3$. %	MgO. %
352	1	2.70	.44	92.96	*52.00*	1.21	*.58*
353	2	3.49	.41	94.74	*53.09*	1.32	*.63*
354	3	1.39	.34	96.87	*54.29*	1.14	*.54*
355	4	.93	.62	95.88	*53.72*	1.14	*.54*
356	5	2.03	.57	96.76	*54.23*	1.22	*.58*
357	6	4.62	.41	91.21	*51.12*	3.54	*1.69*
358	7	1.61	.61	91.64	*51.35*	6.53	*3.12*
359	8	3.25	.37	92.66	*51.93*	2.32	*1.11*
360	9	.87	.24	97.03	*54.38*	.91	*.43*
361	10	1.66	.34	91.05	*51.03*	6.27	*3.00*
362	11	3.37	.62	90.96	*50.98*	3.99	*1.91*
363	12	2.03	.55	95.35	*53.44*	1.14	*.54*
364	13	2.18	.55	93.67	*52.49*	2.59	*1.24*
365	14	3.07	.46	92.36	*51.76*	3.19	*1.52*
366	15	.84	.41	97.92	*54.87*	.96	*.46*
367	16	.85	.48	97.92	*54.87*	.98	*.47*
368	17	1.75	.78	95.77	*53.67*	1.46	*.70*
369	18	2.35	.91	92.45	*51.81*	2.91	*1.39*
370	19	2.46	.52	94.80	*53.13*	1.80	*.86*
371	20	3.09	.55	94.46	*52.94*	1.51	*.72*
372	21	2.28	.48	95.91	*53.75*	1.37	*.65*
373	22	1.82	.55	96.55	*54.11*	1.41	*.67*
374	23	2.39	.50	95.51	*53.53*	1.85	*.88*
375	24	2.74	.54	92.72	*51.96*	3.62	*1.73*
376	25	2.51	.20	95.02	*53.25*	1.32	*.63*
377	26	2.23	.66	95.44	*53.49*	1.41	*.67*
378	27	2.46	.34	93.03	*52.14*	3.80	*1.82*
379	28	3.24	.32	93.91	*52.63*	2.70	*1.29*
380	29	2.76	.18	95.60	*53.58*	1.26	*.60*
381	30	2.73	.09	95.98	*53.79*	1.30	*.62*
382	31	1.98	.43	96.50	*54.08*	1.04	*.50*
383	32	1.80	.27	96.80	*54.25*	1.24	*.59*
384	33	3.30	.30	93.73	*52.53*	2.82	*1.35*
385	34	3.53	.45	92.93	*52.08*	3.05	*1.46*
386	35	1.55	.32	96.63	*54.15*	1.20	*.57*
387	36	9.67	.50	88.11	*49.38*	1.04	*.50*
388	37	7.57	.20	89.42	*50.11*	2.55	*1.22*
389	38	1.82	.71	95.93	*53.76*	1.23	*.59*
390	39	1.43	.42	97.26	*54.51*	.99	*.47*
391	40	2.25	.30	95.80	*53.69*	1.37	*.65*
392	41	2.02	.36	95.10	*53.30*	2.48	*1.18*
393	42	2.30	.48	96.56	*54.11*	2.48	*1.18*
394	43	4.05	.25	93.77	*52.55*	1.06	*.51*

*Analyses furnished by D. N. McLeod Lumber Co., Garnet.
Figures in italics are calculated from original analyses.

Analyses Nos. 352 to 394 are the summary of results from the shallow holes in section 36 which penetrated only to the bottom of the Fiborn limestone. According to these analyses the content of calcium carbonate generally is between 91 and 97 per cent, the magnesian carbonate between 1 and 4 per cent, and the silica between 1 and 3 per cent.

The analyses of the core from the deep test hole show that the Fiborn limestone extends to the depth of about 27 feet. It is underlain by about 14 feet of magnesian limestone which is followed by 35 feet or more of high calcium limestone. Beds belonging to this horizon are

not exposed anywhere as far as known. A nearly complete section of the magnesian horizon above, however, is exposed in a test pit in bottom of Hendrick's quarry a half mile to the south. (See section in Hendrick's quarry, Mackinac county.)

The height of the bluff on the north is from 80 to 100 feet, hence conditions are favorable for quarrying down to the bottom of the lower high calcium hoiizon

Summary. The high calcium limestone resources of Luce county are confined to a very narrow strip along the southern edge of the county, chiefly in section 31, T. 45 N., R. 8 W., and section 36, T. 45 N., R. 9 W.

Mackinac County.

Distribution. The Hendricks series and Fiborn limestone of the lower Niagara underlie the noithwestern part of the county, the Manistique series and the Engadine dolomite of the upper Niagara the remainder of the county (fig. 14) with the exception of St. Ignace peninsula

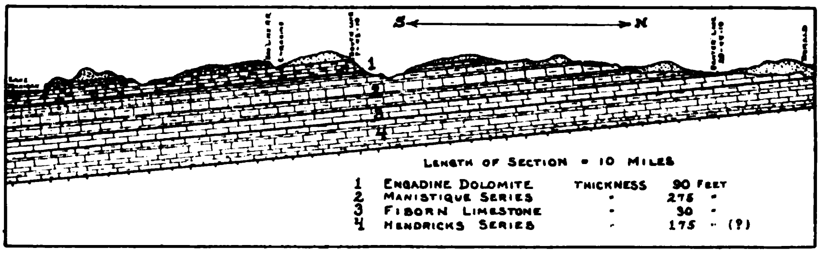


Figure 14. Section from Donald, Mackinac county, south to Lake Michigan.

and adjacent islands, which are underlain by the Monroe-Salina series.

Exposures of all of the members of the Niagara limestone, with the exception of the Hendricks series, are very large and numerous. The Engadine dolomite forms a prominent though broken northward facing escarpment extending from east to west across the county. The Fiborn limestone also terminates on the north in an escarpment, though much less prominent and continuous. It is exposed or is under light drift covei in several large areas throughout a belt extending from the west side of Lake Ella noitheast to Hendricks quarry and then southeast through Fiborn quarry into Chippewa county, where it disappears beneath thick deposits of lake clay. The most important areas of exposures are on the west side of Lake Ella, near Gould City, and in the vicinity of Hendricks and Fiborn quarries. A large exposure is reported to occur between these quarries. The Fiborn limestone is near the surface about one mile south of Donald but the extent of the

area is uncertain. The Engadine dolomite is widely exposed from its escarpment south to the shores of lakes Michigan and Huron. Very large exposures of the Monroe-Salina formation occur in the vicinity of St. Ignace and on the adjacent islands.

Character. The Hendricks series is composed of a variety of limestones ranging in composition from high calcium to high magnesian. They are not well exposed in the county and knowledge concerning their general character has been gained largely from a shallow test pit in Hendricks quarry and from drill cores in its vicinity. The thickness of the series is unknown but it is certainly over 100 feet. The Fiborn limestone, 18 to 30 feet in thickness, is uniformly a buff to dark gray lithographic to densely crystalline high calcium limestone breaking with a perfect conchoidal fracture and generally containing an abundance of small calcite crystals. The Manistique series, probably over 275 feet in thickness, is composed of a variety of limestones varying greatly in texture, structure, and composition. The series, however, is largely high magnesian limestone or dolomite. The Engadine dolomite is everywhere an extremely massive very crystalline bluish or white dolomite with mottlings and streaks of distinct blue and containing many druse cavities. It is generally very pure, the impurities usually being less than 2 per cent. The Monroe-Salina is composed chiefly of argillaceous and siliceous dolomites with intercallated beds of gypsum.

Quarries and Localities.

Fiborn quarry. The Fiborn Limestone Co. have a large quarry in section 16. This quarry (Pl. IV B) was formerly known as the Osborn quarry and was the first to be opened in the Fiborn limestone. In this vicinity limestone is exposed in sections 15, 16, 21, and 22, T. 44 N., R. 7 W. In 1901 A. C. Lane described* some caves in section 16 and incidentally made reference to the purity of this bed. In a later report† he published the following section:

Section in Fiborn Quarry.

	Thickness, feet.
"Limestone with Orthoceras, a loose Favositid, a small gastropod, but most abundant fragments of heads of Stromatoporoids	3
Greenish sandy looking limestone with greenish tubes running into each other (anastomosing), with corals and Stromatoporoids which show well on the green surface	1
Very massive	6
Mottled brown and light with Stromatopora heads	4
Finely banded mud rock (calcilutite) with quite persistent bands of holes, empty gastropod cavities half way down. These have calcite crystals lining them. A leperdita and stylolitic suture occur and this lower part has a more porcelanic and less sugary appearance than the upper part containing the coral and Stromatoporoid heads. A notable thing is the absence of Pentamerus"	9

*Ann. Report, Mich. Geol. Surv., 1901, p. 146.
†Ann. Rept., Mich. Geol. Surv., 1907, p. 20.

The *Fiborn limestone* has been traced from a point two or three miles west of Trout Lake nearly to Manistique River, a distance of about 50 miles. Fragments identical with the Fiborn limestone are abundant in the drift on Lime Island (St. Marys River), indicating its eastward extension from Trout Lake.

The thickness of the bed in the quarry is variable but the maximum is about 30 feet. The average height of the quarry face is probably about 25 feet. A large acreage of stone has been quarried out but this is only a small fraction of the area of easily quarryable stone. The stone is stripped and handled by steam shovel. The stripping is generally thin but locally it is several feet in thickness.

The beds in the quarry are, on the whole, gray to buff gray, lithographic to dense grained, high calcium limestone, very brittle and breaking with a smooth conchoidal fracture and generally containing small disseminated calcite crystals. Locally the stone is finely banded and free from calcite crystals. All of the stone is high calcium but near the bottom of the bed the percentage of magnesia is slightly higher. The floor of the quarry is white or light colored crystalline limestone containing more or less magnesia.

An analysis (No. 395) of a representative set of samples of the Fiborn limestone gave 55.19 per cent of calcium oxide and 1.12 per cent of magnesia. An analysis (No. 396) of a sample from the magnesian basal portion of the bed gave 51.46 per cent of calcium oxide and 4.30 per cent of magnesia. Analyses Nos. 397 to 399 are of the marketable product. These analyses indicate the high average purity of the limestone which is extensively used for flux, chemical lime, the manufacture of calcium carbide, sugar, etc., and for road material, concrete, and railway ballast.

Hendricks quarry. A large area of Fiborn limestone occurs in sections 1 and 2, T. 44 N., R. 9 W., and portions of adjoining sections. The portion of the area extending into the sections on the north is terminated by a bluff 80 to 100 feet in height (see McLeod Lumber Co. quarry, Luce county.) The Union Carbide Co. have opened a large quarry (Pl. V A) at Hendricks near the eastern end of the area in the edge of section 6, T. 44 N., R. 8 W.

The quarry at the time of the writer's visit was an elongated opening over an eighth of a mile in length and from 8 to 25 feet in depth. The section exposed in the quarry and in a test pit (Pl. V B) in the floor of the quarry is as follows:

A. CRUSHING PLANTS OF THE BAYPORT QUARRY OF THE WALLACE STONE COMPANY NEAR BAYPORT, HURON COUNTY.

Worked out portion [illegible] the foreground. The present quarries are beyond the crushing plants.

B. FIBORN QUARRY AND CRUSHING PLANT OF THE FIBORN LIMESTONE COMPANY, MACKINAC COUNTY.

The Fiborn limestone has a maximum thickness of nearly 30 feet in this quarry.

A. HENDRICKS QUARRY OF THE UNION CARBIDE CO., MACKINAC COUNTY.

The Fiborn limestone in this quarry averages about 18 feet in thickness.

B. TEST PIT IN THE FLOOR OF HENDRICKS QUARRY, SHOWING THE UPPER BEDS OF THE HENDRICKS SERIES.

Section in Hendricks quarry.

	Thickness, feet.
1. Hard light gray, porous and thin-bedded magnesian limestone. Stone badly leached. Bed present only in places. Not used	4
2. Hard white to light gray, crystalline to dense grained, porous, cherty, and magnesian limestone. Bed not used. (Anal. No. 400 of beds Nos. 1 and 2 gave 12.71 per cent of MgO)	3½
3. Gray to grayish buff lithographic to dense grained high calcium limestone with a smooth conchoidal fracture and with small disseminated calcite crystals. Top portion is light gray, well bedded and crystalline. (CaO, 55.05 per cent; MgO, 0.81 per cent; Anal. No. 401)	18
Test pit in bottom of quarry.	
4. Hard white dense grained to finely crystalline high calcium limestone, becoming more magnesian toward the base (CaO, 53.89 per cent; MgO, 1.35 per cent. Anal. Nos. 403-4)	8
5. Dark buff gray dense grained high calcium limestone (CaO, 55.29 per cent; MgO, 1.05 per cent. Anal. No. 405)	1
6. Hard white thin-bedded high calcium limestone (CaO, 51.39 per cent; MgO, 4.19 per cent. Anal. No. 406)	2
7. Hard white crystalline dolomite (MgO, 20.46 per cent. Anal. No. 407)	2½
8. Brownish crystalline dolomite with drusy cavities. (MgO, 20.15 per cent. Anal. No. 408)	6
9. Yellowish earthy high calcium limestone (CaO, 55.75 per cent. Anal. No. 409)	1

As may be noted from the above section the Fiborn limestone is locally overlain by beds of light colored magnesian limestone. These beds were encountered only in the southwestern portion of the quarry. The rock suface is more or less corroded and eroded and apparently these magnesian beds are present only in the higher places in the vicinity of the quarry. Some of the corrosion hollows are very deep extending nearly to the bottom of the Fiborn limestone. The hollows or ''pockets'' are filled with drift and give more or less trouble in stripping.

The thickness of the Fiborn member averages about 18 feet which is considerably less than in the Fiborn quarry, Mackinac county, or in the Blaney quarry, Schoolcraft county. The stone, however, is very similar in character and composition in all of the quarries. Analysis No. 400 indicates that magnesian character of the white limestone overlying the Fiborn limestone on the south. An analysis (No. 401) of a set of samples from the Fiborn limestone gave 55.05 per cent calcium oxide and only 0.81 per cent of magnesian oxide. Generally the basal portion is more magnesian but analysis No. 402 from near the bottom of the bed gave 55.29 per cent of calcium oxide and 0.82 per cent of magnesium oxide. The white underlying limestone, which, in the Fiborn and Blaney quarries is magnesian, also is low in magnesia. Analyses Nos. 403 to 409 are of the beds exposed in the test pit and these show that the beds range in composition from very pure high calcium limestone to heavy magnesian limestone or dolomite.

A number of core drillings were made in the vicinity of the quarry and the following analyses are of the core from one over 145 feet in depth:

Test Hole Near Hendrick's Quarry.

Analyses of drill core, sec. 1, T. 44 N., R. 9 W., Mackinac County. Analyses furnished by Joseph Scales, Supt. Union Carbide Co., Sault Ste. Marie, Mich.

Analysis No.	Sample No.	Core.		Silica. SiO_2. %	Iron-Alumina. Fe_2O_3-Al_2O_3. %	Calcium carbonate. $CaCO_3$. %	Calcium oxide. CaO. %	Magnesium carbonate. $MgCO_3$. %	Magnesium oxide. MgO. %	Carbon di-oxide and water. CO_2-H_2O. %	Remarks.
		Thickness, feet.	Depth, feet.								
410	1	9'- 6"	23'- 0"	2.16	1.10	*83.97*	47.06	*12.27*	5.87	43.81	Compare beds Nos. 1 and 2 of section in Hendrick's quarry.
411	2	11'- 0"	34'- 0"	3.88	0.45	*84.56*	47.39	*9.34*	4.47	43.81	
412	3	5'- 6"	39'- 6"	1.02	0.17	*96.69*	54.19	*1.05*	0.50	44.12	Fiborn limestone. Compare bed No. 3.
413	4	10'- 0"	49'- 6"	1.79	0.26	*93.94*	52.65	*2.24*	1.07	44.23	
414	5	6'- 3"	55'- 9"	1.40	0.16	*90.93*	50.96	*6.65*	3.18	44.30	Compare beds Nos. 4-9 of test pit in bottom of quarry.
415	6	6'- 3"	62'- 0"	1.94	0.74	*73.46*	41.17	*22.45*	10.74	45.41	
416	7	9'- 0"	71'- 0"	1.02	0.44	*91.04*	51.02	*5.29*	2.53	44.99	Lower high calcium horizon.
417	8	13'- 6"	84'- 6"	1.57	0.56	*95.34*	53.43	*.29*	0.14	44.30	
418	9	12'- 0"	96'- 6"	1.48	0.36	*91.55*	51.31	*3.74*	1.79	45.06	
419	10	19'- 6"	116'- 0"	3.46	0.57	*86.97*	48.74	*4.70*	2.25	44.98	
420	11	5'- 6"	121'- 6"	2.04	0.40	*91.09*	51.50	*4.01*	1.92	44.59	
421	12	12'- 6"	134'- 0"	3.91	1.27	*66.52*	37.28	*27.55*	13.18	44.36	
422	13	11'-10"	145'-10"	5.72	1.71	*65.07*	36.47	*24.85*	11.89	44.21	

Note.—Numbers in italics are calculated from original analyses.

The exact location of this hole is not given but judging from the magnesian character of the top 20 feet (13 ft. 6 in. to 34 ft.) it is south of the quarry where the overlying white magnesian limestones (Beds Nos. 1 and 2) should be expected. Core samples Nos. 3 and 4 (34 ft. to 49 ft. 6 in.) represent the Fiborn bed but it is probable that a part of the bed is included in samples Nos. 2 and 5. Samples Nos. 5 to 7 (49 ft. 6 in. to 62 ft.) represent the magnesian series exposed in the test pit. Samples Nos. 8 to 11 are of a lower high calcium bed or beds 35 to 50 feet in thickness and comparable in purity with the Fiborn limestone above.

The name Hendricks series has been provisionally given to this series of high calcium and magnesian limestones below the Fiborn limestone. It is possible, however, that the Hendricks series should also include the Fiborn limestone. A large section of this series would be exposed along the high bluff a half mile to the north if the base of the bluff was not covered by debris.

A large part of the quarry product is used by the Union Carbide Co. at Sault Ste. Marie for the manufacture of calcium carbide. The remainder of the product is disposed of for a variety of purposes.

Donald. The Fiborn limestone is near the surface in section 29, T. 44 N., R. 10 E. It is exposed at the depth of about five feet in a shallow open well on the farm of August Wandtland near the center of the section. It was also found at depth of 28 inches in holes dug for telephone poles in the road along the east side of the section. The overburden, however, appears to be heavy in most places and the area of easily quarryable stone is very uncertain. An analysis (No. 423) of a sample blasted from the well on the Wandtland farm gave only 47.72 per cent of calcium oxide and 5.93 per cent of magnesium oxide. The percentage of magnesia is higher than is usual for the Fiborn limestone.

Gould City. Just north and west of Gould City the Fiborn limestone is exposed or near the surface in sections 30 and 31, T. 43 N., R. 11 W., also in the eastern part of sections 25 and 36, T. 43 N., R. 12 W. Fire has removed the timber and soil mold exposing a large area of bare rock on each side of the road. The area of easily quarryable stone is uncertain but apparently it is several hundred acres.

The stone is a light gray, lithographic, high calcium limestone, very brittle, breaking with a smooth conchoidal fracture and containing small disseminated calcite crystals. An analysis (No. 424) of sample taken from a small pit near the road in section 31 gave 54.30 per cent of calcium oxide and 1.63 per cent of magnesium oxide. The light

drift cover and the nearness to the Minneapolis and St. Paul railroad make very favorable conditions for development.

Hunt Spur. Two miles north of Hunt Spur the Fiborn limestone is exposed over an area of several square miles in extent. Fire has removed much of the timber and original soil mold, and exposures are numerous from the vicinity of Lake Ella westward into section 4, T. 42 N., R. 13 W., Schoolcraft county, a distance of about six miles. This is the largest area of exposures of the Fiborn limestone. The principal exposures in Mackinac county are in sections 5 and 6, T. 42 N., R. 12 W., and in sections 31 and 32, T. 43 N., R. 12 W. The rock surface is generally flat but locally there are rock ridges from 4 to 20 feet in height. The thickness of the Fiborn limestone in the eastern portion of the area is variable but uncertain, but in the Blaney quarry at the west end it is at least 26 feet. Quarrying conditions are favorable in much of the area but drainage in some portions would be difficult. An analysis (No. 425) of limestone from a rock ridge 15 to 20 feet in height in section 6, T. 42 N., R. 12 W., was made by the Lake Superior Iron & Chemical Co. and this gave 53.70 per cent of calcium oxide and 1.74 per cent of magnesium oxide. Other analyses from the western portion of the area also show the high average quality of the limestone.

Another area of exposures is reported to occur between Fiborn and Hendricks quarries. About four miles northwest of Trout Lake in section 24, T. 44 N., R. 7 W., small exposures of the Fiborn limestone occur and it is probable that with further search and exploration a considerable area of high calcium limestone may be developed. Most of the locality is covered by morainic deposits, therefore the areas of limestone under light overburden may be small.

Ozark quarry. The Ozark Stone Co. has opened a quarry (Pl. VI A) at Ozark in the edge of the prominent escarpment of Engadine dolomite which extends northward to Haff postoffice (Dick) in Chippewa County. This dolomite is exposed or is at shallow depth in many places in an area of many square miles in extent east and north of Ozark. The amount of available dolomite in this area alone is practically inexhaustible. The dolomite is distinctly bluish with mottlings and streaks of blue, very crystalline, massively but poorly bedded, and very porous, locally containing many druse cavities, apparently the molds of a large species of Pentamerus. The jointing is very irregular and upon blasting the stone breaks into large irregular masses. At the time (1913) of the writer's visit, the quarry was about 100 feet in length and 20 feet in depth but the bottom of the bed had not been reached. The rock surfaee is very uneven and the thickness of the bed is variable

and uncertain. Three or four miles north, however, it is over 50 feet. The stone is very pure dolomite, suitable for use as a basic lining in open hearth furnaces and for the manufacture of paper by the sulphite process. Analysis No. 426 indicates that at Ozark the impurities average less than one-half per cent.

Kenneth. Exposures of Engadine dolomite occur at and in the vicinity of Kenneth and formerly a small quarry was operated here for burning lime. The dolomite is similar to that at Ozark, though judging from analysis No. 428 it is slightly less pure, containing 1.40 per cent of impurities.

Large areas of Engadine dolomite occur in the eastern part of the county, especially in T. 42 N., R. 1 W., and 43 N., R. 2 W. The northern limit of these areas is generally marked by high rock bluffs.

Caffey. A considerable area of Engadine dolomite occurs a mile southeast of Caffey. Dolomite is exposed in a number of places and quarrying conditions are favorable.

Garnet. A small exposure of Engadine dolomite occurs at the top of a low elevation a short distance north of the railroad at Garnet, but judging from the great number of large boulders the dolomite is near the surface in an area of at least two or three hundred acres.

Engadine. About one mile west of Engadine the Minneapolis, St. Paul and Sault Ste. Marie railroad crosses a large exposure of bluish very crystalline extremely massive and poorly bedded dolomite, locally containing numerous druse cavities, apparently the molds of a large Pentamerus. Exposures extend for two miles south of the railroad and apparently southwestward for several miles. The rock surface slopes gently to the south, apparently in accordance with the general southward dip of the beds, but north of the railroad the area terminates in a series of low bluffs. About one mile south of the railroad there is an east and west valley locally bordered by perpendicular rock walls 8 to 12 feet in height on the north and south. One mile north of the railroad the massive dolomite terminates in a high bluff with an exposure at the base of very fossiliferous and thin bedded magnesian limestone, belonging to the underlying Manistique series. The name Engadine dolomite has been given to this massive dolomite from its prominent and extensive exposures west of the village of Engadine.

According to analyses Nos. 429 to 431 the rock is a normal dolomite containing about 1.25 per cent of impurities. The amount of available dolomite in the Engadine area is practically inexhaustible but unfortunately dolomite finds but limited use in the industries. The large

area of exposures, a natural face, and the proximity to railroad transpoitation offer especial advantages for development.

St. Ignace. Large exposures of the Monroe dolomites occur in the vicinity of St. Ignace, on Mackinac Island and other adjacent islands. Formerly the dolomite was burned for lime at a number of places. Due to the exhaustion of suitable fuel and to the impure character of the dolomite these quarries and kilns were abandoned many years ago. Much of the Monroe dolomite in the vicinity of St. Ignace and on Mackinac Island is brecciated.

Summary. Mackinac county contains several of the largest areas and also the largest reserves of high calcium limestone in the Northern Peninsula, but unfortunately most of these are located in the northwestern part of the county at considerable distance from trunk line railroads. Only two of the areas have been developed, though the limestone is suitable for almost every purpose for which high calcium limestone may be used. The county has also practically inexhaustible supplies of the purest dolomite, much of which is near railroad transportation. The exceptional purity of the dolomite makes it especially adapted for use as the basic lining in open hearth furnaces and for use in paper manufacture by the sulphite process.

Marquette County. Exposures of the Trenton limestone and the Beekmantown (Calciferous) sandstone occur along the Escanaba River in the extreme southern part of the county. Analyses Nos. 437 to 439 are indicative of the sandy character of the Beekmantown and Nos. 440 and 441 of the siliceous and argillaceous character of the Trenton limestone.

Menominee County.

Distribution. The Trenton limestone underlies the much larger eastern portion of Menominee county and the Beekmantown (Calciferous) forms a narrow belt along the western side. The Trenton is exposed about 2 miles north of Menominee and also in the bed of Menominee River near its mouth. The Beekmantown sandstone is exposed in the vicinity of Hermansville and along the Grand rapids on Menominee River. Rominger* gives the following section from this place:

*C. Rominger, Paleozoic Rocks of the Upper Peninsula, Vol. I, Pt. III, p. 72, 1869-1873.

Section of the Calciferous sandstone at Grand rapids, Menominee River.

		Thickness, feet.
1.	Fine grained crystalline even-bedded limestone with argillaceous partings. (SiO_2, 18 per cent, Anal. No. 442)	4
2.	Nodular limestone of peculiar concentrically laminated structure much resembling irregularly contorted nodular masses of Stromatopora	3
3.	Compact dolomites, partly arenaceous, partly of oolitic structure	2
4.	Fine grained argillaceous arenaceous limestones banded with red stripes or variegated with irregular blotches in thin and even bedded layers. (SiO, 23 per cent, Anal. No. 443)	3
5.	Hard dolomitic limestones and öolite beds mixed with a greater or smaller proportion of quartzose sand granules	4
6.	White coarse grained sandstone variable in hardness and with seams of arenaceous shales. Numerous angular fragments of limestone and pieces of shale in the upper layers	5

The siliceous, argillaceous, and magnesian character of the limestone beds is indicated by the analyses by Rominger, No. 442 of the upper bed, No. 443 of bed No. 4, and No. 444 of bed No. 5.

Hermansville. Sandy limestone belonging to the Beekmantown (Calciferous) is exposed in the vicinity of Hermansville, Iron Mountain, and Waucedah, and has been locally designated* by Rominger as the Hermansville limestone. Its general character as described by him is "that of a coarse grained sandstone with abundant calcareous cement in alternation with pure dolomite or sometimes öolitic beds." It is of little economic importance, the stone apparently being suitable only for road material, concrete, common building stone, etc.

The principal exposure of the Trenton limestone is about 2 miles north of Menominee where a small quarry has been opened by the Menominee Stone Crusher Co. The area of easily quarryable stone is apparently only 10 or 15 acres but perhaps further exploration may result in the development of a considerable larger area.

The stone is a buff to gray, argillaceous, low magnesian stone weathering to bluish color. The argillaceous matter is chiefly in very fine wavy laminations more or less parallel with the bedding. Only four or five feet of rock were exposed but according to the foreman of the quarry the rock is similar to the depth of about 34 feet. The rock is used chiefly for concrete paving and for road making in the vicinity of Menominee.

Analysis No. 445 is indicative of the argillaceous and low magnesian character of the beds in the quarry. Analysis No. 446 from the field notebook of N. H. Winchell is apparently from the upper dolomite beds, the so-called "Menominee marble," exposed along Menominee river. The impurities, however, in this bed are abnormally low for the Trenton limestone.

Summary. Menominee county apparently has limited limestone

*C. Rominger, Paleozoic Rocks, Mich. Geol. Surv., Vol. I, Pt. III, 1873, p. 81.

resources and these are generally siliceous, argillaceous, and magnesian. The limestone is adapted chiefly for road making, concrete, railroad ballast, or rough building stone.

Monroe County.

Distribution. The Monroe formation and the Dundee limestone occupy all but the extreme southwestern portion of the county. In Monroe county the Monroe formation consists of three divisions, viz., the Lower Monroe or Bass Island series, the Middle Monroe or Sylvania sandstone, and the Upper Monroe or Detroit River series. The members of the Monroe formation and the Dundee limestone form parallel belts extending across the county in a northeast-southwest direction. The Lower Monroe occupies the southeastern belt along Lake Erie and the others follow in order to the northwest.

Character. The Lower Monroe is composed of argillaceous and locally bituminous dolomite, anhydrite, celestite, and native sulphur; the Sylvania, of white sandstone and sandy dolomite; the Upper Monroe, chiefly of argillaceous dolomite with anhydrite, celestite, and sulphur; the Dundee, high calcium and magnesian limestone. The dolomite of the Monroe is locally much brecciated.

Quarries and Localities.

The surface deposits are generally thin in the eastern part of the county and gradually increase in thickness westward. Because of this, exposures decrease in number from near the lake westward. The lower Monroe dolomite of the eastern belt is exposed at many places but the Dundee limestone of the western belt is exposed at but three places.

Lower Monroe.

Monroe quarries. Formerly numerous limestone quarries were operated in the eastern portion of Monroe county but only three quarries are now in operation and these are at Monroe.

The quarry of the Shore Line Stone Company is about one mile north of the city near the Shore Line Railroad. The following section was exposed:

		Thickness, feet.	Inches.
	Stiff lake clay	4–6	
1.	Blue and buff dolomite	2–4	
2.	Dark gray, buff, brown, bituminous, argillaceous and massively bedded dolomites	18	
3.	Dark gray drusy and argillaceous dolomite. Light colored dolomitic oölite	1+	
4.	Light to dark gray and dense grained brittle dolomite with bluish mottlings and streaks resembling castile soap. The upper 8 to 10 inches has a gnarled pattern, the middle 6 inches is mottled, and the lower 3 or 4 feet streaked. The lower portion is very argillaceous	5	
5.	Dark gray densely crystalline dolomite with delicate bituminous laminations	2	
6.	Buff very earthy argillaceous and massively bedded dolomite	3	
7.	Dark gray densely crystalline dolomite	2	
8.	Thin seam of oölitic dolomite	0	6
9.	Brittle light colored dolomite with black mottlings and streaks and a blue shale seam at the bottom	1	6
10.	Dark buff gray crystalline and sandy appearing dolomite with a shale seam at the bottom	2	
11.	Thin seam of oölitic dolomite	0	4–6
12.	Brittle fine grained light colored argillaceous dolomite with bluish streaks and mottlings. Lower portion very argillaceous	1+	

Much of the dolomite is argillaceous though analyses (Nos. 447-449) of samples taken at 2, 7, and 10 feet from the top of the quarry gave an average of only 0.75 per cent iron and alumina and 1.35 per cent of silica. The sulphur is locally high and the generally impure character of the dolomite unfits it for general fluxing and chemical purposes. In the early days it was used for lime burning and building stone but now it is used chiefly for road making, concrete, and railroad ballast.

The quarry of the France Stone Co., formerly the Monroe Stone Co., is on the southeast side of Plum Creek in the southern part of Monroe. This is the largest quarry in the county and the company have recently installed a modern crusher plant (Pl. VI B). The area of available stone is said to be about 90 acres. The section exposed is as follows:

Section in the France Stone Co. quarry.

		Thickness, feet.
	Surface	0–4 +
1.	Light yellowish earthy dolomite with brown mottlings with oölite at the top	3
2.	Light bluish gray densely crystalline dolomite	2
3.	Buff gray very fine grained, laminated and bituminous dolomite	5
4.	Dark gray bituminous and densely crystalline dolomite with drusy cavities	2
5.	Massive gray dolomite	3
6.	Dolomite breccia; angular fragments very large and many of the original interstitial openings partially filled with dolomite spar and large crystals and masses of calcite or dog-tooth spar	6
7.	Buff sandstone	2
8.	Brittle yellowish white and buff dolomite with mottlings and streaks	
9.	Dark buff gray dense grained to crystalline and bituminous dolomite with druse cavities	2
10.	Dolomite breccia, fragments very small	1
11.	Massive crystalline dolomite resembling brown sugar	1+

The maximum depth of the quarry is about 40 feet but a complete section could not be obtained at any place on account of a large blast of limestone. Some of the beds are much brecciated. In some places

the brecciation is confined to one bed, in others it extends through all. The brecciation is of two types, one in which rearrangement of the fragments has occurred and one in which it has not. In the first type the fragments are large and are inclined at all angles. In the second type they are generally small and are difficult of recognition. Usually a very hackley fracture of the stone is indicative of this type of brecciation.

Many of the beds are argillaceous and bituminous. An average of five analyses (No. 450) of the gray dolomite beds gave 3.08 to 6.08 per cent of impurities. The stone is crushed for concrete, road making and railroad ballast.

Immediately north of the France quarry on the opposite side of Plum Creek there is a small quarry operated by J. Morris for rough building stone, concrete, and road material. The beds are similar to those in the France quarry.

According to Sherzer* stone was formerly quarried near Newport Center and Brest, claim No. 529, south of Swan Creek, in the bed of the River Raisin for three or four miles above Monroe, a half mile south of Plum Creek quarries, in the bed of Otter Creek for a mile up stream from the Pere Marquette railroad bridge, along the south branch of Otter Creek in sec. 20, T. 7 S., R. 8 E., along Muddy Creek in secs. 29, 32, and 33 of the same township, in secs. 1 and 12, T. 8 S., R. 7 E., in sec. 15 in the vicinity of Little Lake, in secs. 10, 16 and 21 of the same township, in sec. 25, T. 8 S., R. 6 E., and sec. 4, T. 9 S., R. 6 E. Nearly all of these quarries were small and were operated for building stone for local use. Lime, however, was burned at some. All of the quarries are abandoned or idle and full of water. The area of easily quarryable stone is reported to be considerable in some of the localities. The beds are chiefly gray argillaceous dolomite with öolitic horizons, similar in general character to the beds exposed in the Monroe quarries.

Upper Monroe.

The exposures of the Upper Monroe are numerous and many small quarries have been opened at one time or another, chiefly for building stone. Lime was burned but much of the dolomite is too sandy or impure for this purpose.

Woolmith† *quarry.* The Woolmith quarry is between Maybee and Scofield and is the largest in the Upper Monroe. The quarry is full of water but according to Sherzer the section formerly exposed was as follows:

*W. H. Sherzer, Geology of Wayne Co., Vol. VII, Pt. I, pp. 92-100, Mich. Geol. Surv., 1900.
†W. H. Sherzer, Geology of Monroe County, Vol. VII, Pt. I, 1900, pp. 78-82.

A. QUARRY OF THE OZARK STONE COMPANY AT OZARK, MACKINAC COUNTY.

The massive bedding and the irregular jointing are characteristic of the Engadine dolomite.

B. NEW CRUSHING PLANT OF THE FRANCE STONE COMPANY, MONROE, MONROE COUNTY.

The beds belong to the Raisin River dolomite of the Lower Monroe and are locally much brecciated.

		Thickness, feet.
	Blue boulder clay	2–8 +
A.	Light colored finely laminated dolomite blotched and streaked with brown	2–4
B.	Dolomitic öolite with small cavities containing celestite, calcite, and sulphur	3½
C.	Drab to brown dolomite with the upper surface very hummocky with cavities containing celestite, calcite, and sulphur. A thin seam of impure asphaltum is at the top and bottom of this bed	1–3
D.	Dark brown to gray dolomite more or less impregnated with oil	1–5
E.	Brown porous dolomite impregnated with oil and containing cavities with celestite, calcite, and sulphur. "Sulphur bed"	1–3
F.	Sandy bluish dolomite and bituminous limestones blotched with brown toward the bottom	2–3
G.	Gray very sandy dolomite	3–4
H.	Light gray sandy and massive dolomite with streaks of "glass sand" and iron oxide. (Insoluble residue 24.4 per cent, chiefly white sand). Used for building blocks	16
I.	Compact gray and massively bedded dolomite. This bed rests on the Sylvania sandstone	15

Most of the beds are very sandy and portions of the lower beds are pure sandstone. The dolomite also contains sulphur. It is suitable chiefly for rough building stone, road material, concrete, and railroad ballast. Blocks of almost any size may be quarried from the 16 ft. bed. Analyses Nos. 451-452 are indicative of the siliceous character of the beds.

There are six old quarries in the vicinity of Raisinville. The exposed beds correspond to the lower beds in the Woolmith quarry. Lime was burned at one of the quarries. Analysis No. 453 is indicative of the general character of the beds.

Lulu quarry. This quarry is located in the NW. ¼ NW. ¼ sec. 16, T. 7 S., R. 7 E. The beds include both sandstone and gray dolomite more or less mottled and streaked with blue. Building stone was quarried here more than 75 years ago. Analysis No. 454 by Rominger is from one of the beds of dolomite and No. 455 from a sandy stratum.

Little Sink quarry. In Little Sink quarry, SE. ¼ SE. ¼ sec. 2, T. 8 S., R. 6 E., 6 to 8 feet of gray dolomite overlies pure white sandstone. The beds were quarried for building stone and for burning lime.

Ottawa Lake quarries. Several small quarries were formerly operated near the north end of Ottawa Lake for building stone, lime, and road material. The beds formerly exposed are as follows:

		Thickness, feet.
A.	Compact buffish brown siliceous dolomite	0–?
B.	Cherty dolomite	1–1½
C.	Compact dolomite similar to A but blue in color	9+
D.	Buff to gray compact dolomite with carbonaceous films	2

Ida quarries. In some quarries one and one-half miles west of Ida there are two beds of gray dolomite. The upper is oolitic and has a gashed or acicular structure. Analysis No. 457 is from the upper bed. The gashed structure is apparently due to tabular crystals of celestite which have been leached out.

Analysis No. 456 is from material from a drill hole in the Upper Monroe dolomite just north of Carleton.

Dundee Limestone.

Quarries have been opened in the Dundee limestone at Dundee and near the mouth of Macon River about 2 miles northeast of Dundee.

Dundee quarry. This quarry is located on the north bank of the River Raisin back of the National Hotel. It consists of a rectangular opening about 90 feet wide and 240 feet long, and is only a few feet above normal river level. It is abandoned and full of water. According to local residents all of the available stone has been removed. The section as determined by Sherzer* is as follows:

		Thickness, feet.
A.	Gray fossiliferous limestone impregnated with oil	2½
B.	Grayish brown limestone, weathering bluish	4½
C.	Dark brown and bituminous limestone, cherty toward the bottom	6½
D.	A massively bedded bluish limestone, lighter colored toward the bottom	5

Macon quarry. The Macon quarry has been known at various times as the Christiancy, Nogard, and Bullock quarry, corresponding with its various owners. It is near the mouth of Macon River and in the former channel of the river, from which the water has been deflected by an embankment. It extends for a considerable distance along the north bank of the stream. It is now abandoned and full of water, hence its description rests upon the authority of Sherzer†.

		Thickness, feet.
	Surface	4–6 +
A.	Gray fossiliferous limestone. ($CaCO_3$, 90.80 to 98.10 per cent; $MgCO_3$, 6.87 to 0.63 per cent; Anal. Nos. 458 and 463)	1–2
B.	Compact brownish and bituminous limestone, weathering bluish; cherty toward the bottom with a seam of chert between beds B and C. ($CaCO_3$, 86.80 per cent; $MgCO_3$, 11.60 per cent; Anal. No. 459)	4–4½
C.	Soft dark gray limestone. ($CaCO_3$, 77.60 per cent; $MgCO_3$, 17.41 per cent; Anal. No. 460)	7–8
D.	Similar but higher in calcium carbonate. ($CaCO_3$, 95 per cent; $MgCO_3$, 3.86 per cent; Anal. No. 461)	8

The area under relatively thin drift is apparently between 100 and 200 acres but definite data is lacking though the property has been more or less completely tested by the drill. The area of thin overburden lies between the Macon and River Raisin on the southwest and Saline river on the east and northeast. The surface is only a few feet above the level of these streams which are subject to floods, especially in the spring. To control the flood waters of the Macon a canal from 4 to 6 feet in depth was cut out of solid limestone from the mouth of the

*W. H. Sherzer, Geology of Monroe County, Vol. VII, Pt. I, pp. 77-78, Mich. Geol. Surv. 1901.

†W. H. Sherzer, Geology of Monroe County, Vol. VII, Pt. I, pp. 75-76, Mich. Geol. Surv., 1900.

stream up for a half mile or more. This will doubtless lessen the violence of the floods but it is very probable that flood waters will give more or less trouble in quarrying operations. Beds A and B and a portion of C are well exposed along the banks of the canal.

In composition Beds A and D are high calcium containing from about 90 to 98 per cent of calcium carbonate, (Anal. Nos. 458 and 463) but B and C contain from about 10 to over 17 per cent (Anal. Nos. 459, 460, 462) of magnesium carbonate.

Petersburg. Stone has been removed from the bank of Raisin River and in digging ditches, though no real quarry has been developed. Limestone is said to have been struck at a depth of 4 or 5 feet on the river flats in the SE. ¼, NW. sec. 4 (T. 7 S., R. 6 E.) and at 15 to 24 inches in NW. ¼ NW. ¼ sec. 31. Apparently the limestone at the latter place is highly magnesium.

Summary. In Monroe county there are numerous exposures and areas of easily quarryable stone in the belts underlain by the Upper and Lower Monroe dolomites. The dolomite is generally more or less argillaceous and siliceous, and locally brecciated and contains much sulphur. The harder beds are quarried for rough building stone and crushed for road making, concrete, and railway ballast. The Dundee limestone is exposed or near the surface in only a few places and apparently the most important of these is at the mouth of the Macon river. The beds include both high calcium and low magnesium lime. stone.

Presque Isle County.

Distribution. In Presque Isle county, the Dundee limestone underlies a belt skirting the shore of Lake Huron from False Presque Isle northwest into Cheboygan county. The Bell shale, the Long Lake series, the Alpena limestone and the Upper Traverse or Thunder Bay series of the Traverse formation form belts parallel to the Dundee limestone and occupy the remainder of the county excepting the southwestern corner. The Dundee is extensively exposed in the vicinity of Rogers City and Adams Point. The Long Lake series forms a belt of prominent but broken escarpments across the county more or less parallel to the shore of Lake Huron.

The Alpena limestone forms a broad broken ridge extending from the vicinity of Onaway southeast into Alpena County. The exposures are very numerous and many of them very large. The Upper Traverse series is buried under the thick drift deposits of the southwestern portion of the county.

Quarries and Localities.

Dundee Limestone.

Rogers City. The largest and most important exposures of the Dundee limestone occur in the vicinity of Rogers City. The chief exposure is a high ridge of limestone extending parallel to the shore of Lake Huron from near Swan river west-northwest to beyond Rogers City, a distance of about 5 miles. The eastern portion of the ridge is thinly drift covered and rock is exposed over considerable areas. In places, there are old lake beaches of sand and gravel. The west end of the ridge is partially covered by drift.

A prominent bluff extends along the shore. The top of the bluff is from 50 to 80 feet above the lake. The surface rises gradually toward the south to the maximum height of 160 feet or more at the distance of a little more than a mile. The surface then slopes into a valley on the south parallel to the ridge. The slope is apparently more or less in accordance with the inclination of the beds which is about 40 feet per mile toward the south-southwest. According to the records of wells the bottom of the valley is underlain by shale apparently the Bell shale. Limestone, typical of the Lower Traverse, is exposed in shallow wells on the south side of the valley in sections 2 and 3, T. 34 N., R. 5 E.

Limestone breccias occur at several places along the lake shore at and below water level. These belong to what Grabau* has termed the Mackinac limestone. These breccias were formerly included in the Monroe formation. The section of the Dundee limestone extends from water level to a height reported to be 160 feet above Lake Huron. If allowance is made for a dip of 40 feet per mile, the total thickness would be approximately 200 feet. The maximum thickness is probably greater than this for the top of the ridge has suffered considerable erosion. Figure 15 shows the general geological relations in the vicinity of Rogers City.

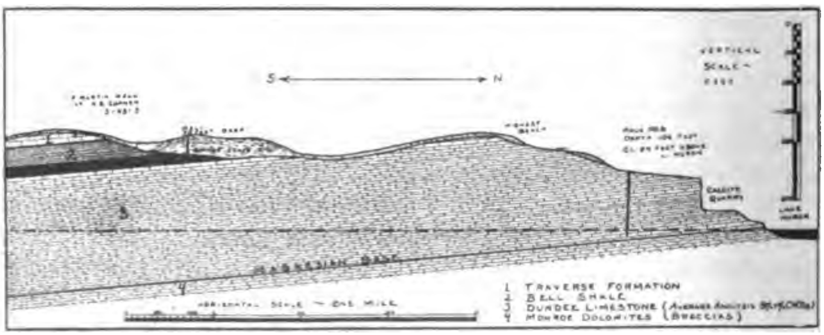


Figure 15. Cross section, Calcite quarry, Presque Isle county to section 3, T. 43 N., R. 5 E.

*A. W. Grabau. The Devonian Formations of Michigan. Unpublished Mss.

A. QUARRY OF THE MICHIGAN LIMESTONE AND CHEMICAL COMPANY AT CALCITE, PRESQUE ISLE COUNTY.

This is probably the largest quarry in the world. The quarry face is more than a mile in length and in places fifty feet in height.

B. PLANT OF THE MICHIGAN LIMESTONE AND CHEMICAL COMPANY AT CALCITE, PRESQUE ISLE COUNTY.

This is one of the largest and most modern plants in the world.

A. MIDDLE BLUFF, FAYETTE, GARDEN PENINSULA, DELTA COUNTY.

The bluff, about 125 feet in height, is composed of heavy magnesian limestone of the Manistique series. Formerly the Jackson Iron Company utilized the limestone in smelting iron. The old quarry face is shown at the right center and the tops of old charcoal kilns in the foreground.

B. JOHN BICHLER QUARRY, FOUR MILES NORTH OF ESCANABA, DELTA COUNTY.

The beds exposed belong to the Trenton formation and are low magnesian argillaceous limestones.

Calcite quarry. The Michigan Limestone and Chemical Co. of Rogers has opened a very large quarry (Pls. VII A and B) in the eastern portion of the ridge at Calcite. The quarry was developed in the bluff along the lake. It extends from Calcite westward for more than a mile.

The floor of the quarry is from 30 to 35 feet above the lake and the working face is from 30 to over 50 feet in height. The face increases in height as quarrying progresses toward the south because of the increase in the elevation of the rock surface and, at the distance of about a mile from the present face, will be more than a hundred feet high, the floor of the quarry remaining at the present elevation. The quarry is one of the largest, if not the largest, and most modernly equipped quarries in the world.

The beds of the Dundee are dark gray to buff, or "chocolate colored," very bituminous and crystalline, high calcium limestone. Most of them are exceptionally pure. Mr. C. D. Bradley, General Manager, kindly placed at the disposal of the writer a large number of analyses of cores from test holes in the vicinity of Rogers City. The average (see Anal. No. 464) of 235 analyses of the upper 50 feet of cores gave 97.85 per cent of calcium carbonate, 1.26 per cent of magnesium carbonate and 0.34 per cent of silica. Certain thin beds however contain from 3 to 10 per cent of magnesium carbonate and locally the percentage of magnesia for a series of beds is from 3 to 6 per cent. The basal beds of the Dundee contain from 5 to 13 per cent or more of magnesium carbonate (Anal. Nos. 486-7, 527, 594-597 and 664).

Hole No. 5.

1350′ N. 50′ W. of S. ¼ post Sec. 23, T. 35 N., R. 5 E.
Elevation 86.2 feet above Lake Huron.

No. of Anal.	Depth.	$CaCO_3$.	SiO_2.	$MgCO_3$.	$FeAl_2O_3$.	$CaSO_4$.
469	5- 8 ft.	98.30	0.32	1.11	0.16	trace
470	8-11 ft.	97.81	0.26	1.42	0.32	trace
471	11-14 ft.	97.50	0.53	1.59	0.31	trace
472	14-17 ft.	96.92	0.45	1.98	0.25	.057
473	17-22 ft.	96.78	0.35	2.61	0.18	.080
474	22-24 ft.	97.28	0.36	1.46	0.63	trace
475	24-31 ft.	97.12	0.41	2.28	0.15	.073
476	31-37 ft.	96.47	0.46	2.59	0.20	.061
477	37-40 ft.	96.14	0.37	3.33	0.15	.075
478	40-48 ft.	89.30	0.41	9.80	0.21	.060
479	48-52 ft.	95.33	0.37	3.87	0.19	.061
480	52-55 ft.	91.56	0.45	7.57	0.22	.061
481	55-61 ft.	95.36	0.23	4.16	0.16	.061
482	61-63 ft.	93.11	0.13	5.37	0.15	.050
483	Average 0-40′.	97.09	0.39	....	....	....
484	Average 40-58′.	92.55	0.33	....	....	....
485	Average 0-58′.	95.29	0.37	3.58	0.23	....
	Washings.					
486	70- 80 ft.	86.54	3.40	7.34	0.99	.200
487	80- 90 ft.	81.25	3.02	13.88	0.64	.160
488	90-100 ft.	62.70	2.64	32.98	0.62	.190
490	90-100 ft.	68.54	2.85	26.54	0.81	.220

Drill Hole No. 6.

Calcite quarry, Michigan Limestone and Chemical Co., Rogers City, Presque Isle Co.
S. ¼ post of Sec. 23, T. 35 N., R. 5 E.
Elevation 105.4 ft. above Lake Huron.

No. of Anal.	Depth.	$CaCO_3$.	SiO_2.	$MgCO_3$.	$FeAl_2O_3$.	$CaSO_4$.
	Surface rock	98.76	0.01	0.98	0.15	0.022
491	6-8 ft	98.82	0.24	1.11	0.17	0.010
492	8-10 ft	97.50	0.17	0.94	0.13	0.040
493	10-12 ft	97.37	0.26	0.98	0.11	0.050
494	12-14 ft	98.39	0.21	0.94	0.11	0.040
495	14-16 ft	97.23	0.25	0.94	0.14	0.040
496	16-18 ft	98.46	0.21	1.21	0.22	0.015
497	18-20 ft	98.49	0.33	0.96	0.21	0.029
498	20-22 ft	98.77	0.08	0.95	0.11	0.050
499	22-24 ft	98.56	0.13	1.06	0.16	0.060
500	24-26 ft	98.42	0.17	1.11	0.20	0.070
501	26-28 ft	98.77	0.12	1.06	0.19	0.070
502	28-30 ft	98.47	0.08	1.25	0.11	0.060
503	30-32 ft	98.02	0.22	1.43	0.16	0.070
504	32-34 ft	98.27	0.22	1.04	0.17	0.060
505	34-36 ft	98.13	0.34	1.06	0.12	0.070
506	36-38 ft	98.49	0.26	1.13	0.15	0.070
507	38-40 ft	98.54	0.25	1.04	0.16	0.080
508	40-42 ft	95.76	0.38	3.16	0.31	0.070
509	42-44 ft	97.39	0.29	1.70	0.19	0.070
510	44-46 ft	97.89	0.28	1.21	0.20	0.150
511	46-48 ft	97.47	0.23	1.08	0.16	0.060
512	48-50 ft	97.82	0.27	1.38	0.13	0.050
513	50-52 ft	97.68	0.27	1.51	0.17	0.060
514	52-54 ft	97.71	0.34	1.13	0.12	0.070
515	54-56 ft	96.16	0.25	1.13	0.12	0.050
516	56-58 ft	90.58	0.67	7.21	0.30	0.070
517	58-60 ft	97.06	0.47	1.34	0.17	0.050
518	60-62 ft	97.54	0.43	1.02	0.12	0.070
519	62-64 ft	97.37	0.30	0.87	0.08	0.080
520	64-66 ft	97.41	0.35	1.44	0.16	0.090
521	66-72 ft	97.32	0.34	1.55	0.14	0.060
522	72-76 ft	95.05	0.36	3.80	0.20	0.050
523	76-82 ft	93.00	0.32	6.56	0.19	0.060
524	82-88 ft	88.43	0.22	10.89	0.24	0.080
525	88-104 ft	90.95	0.23	7.70	0.34	0.050
526	Average 82′	97.18	.27	1.93	.16	loss .46
527	Average 82-104′	90.26	.23	8.57	.31	86.76
528	Average 104′	94.85	.26	3.47	.19	91.26

Drill Hole No. 7.

On section line 1320′ E. of S. W. cor. Sec. 23, T. 35 N., R. 5 E.
Elevation 110 ft. above Lake Huron.

No. of Anal.	Depth.	$CaCO_3$.	SiO_2.	$MgCO_3$.	$FeAl_2O_3$.	$CaSO_4$.
529	4- 6 ft	98.21	0.34	1.13	0.18	0.03
530	6- 8 ft	98.30	0.27	1.08	0.16	0.04
531	8-10 ft	98.23	0.30	1.04	0.17	0.05
532	10-12 ft	98.42	0.29	1.00	0.14	0.05
534	12-14 ft	98.21	0.19	0.87	0.09	0.05
535	14-16 ft	96.92	0.16	2.12	0.09	0.07
536	16-18 ft	97.68	0.20	0.98	0.15	0.05
537	18-20 ft	98.48	0.18	0.72	0.11	0.05
538	20-22 ft	98.13	0.20	0.95	0.24	0.12
539	22-24 ft	98.64	0.11	0.95	0.17	0.06
540	24-26 ft	98.08	0.18	1.23	0.13	0.08
541	26-28 ft	98.39	0.23	0.78	0.09	0.11
542	28-30 ft	98.39	0.27	1.02	0.12	0.06
543	30-32 ft	97.41	0.27	1.44	0.11	0.09
544	32-34 ft	97.14	0.26	1.48	0.13	0.10
545	34-36 ft	97.14	0.53	1.17	0.17	0.09
546	36-38 ft	98.02	0.20	1.42	0.10	0.07
547	38-40 ft	98.35	0.24	1.32	0.10	0.10
548	40-42 ft	98.45	0.23	1.19	0.11	0.09
549	42-44 ft	98.06	0.46	1.06	0.13	0.08
550	44-46 ft	97.66	0.33	1.15	0.15	0.09
551	46-48 ft	97.61	0.28	1.17	0.19	0.09
552	48-50 ft	97.55	0.46	1.40	0.16	0.11
553	50-52 ft	97.89	0.27	1.34	0.13	0.07
554	Average	98.00	.27	1.16	.14	.075

Drill Hole No. 8.

On west side of section 26, T. 35 N., R. 5 E.
Elevation 130 ft. above Lake Huron.

No. of Anal.	Depth.	$CaCO_3$.	SiO_2.	$MgCO_3$.	$FeAl_2O_3$.	$CaSO_4$.
555	0-20 ft	96.32	.22	1.68	.36	....
556	20-35 ft	96.57	.23	1.68	.34	....

Drill Hole No. 9.

Near S. ¼ post, sec. 22, T. 35 N., R. 5 E.
Elevation 94 ft. above Lake Huron.

No. of Anal.	Depth.	$CaCO_3$.	SiO_2.	$MgCO_3$.	$FeAl_2O_3$.	$CaSO_4$.
557	0- 9 ft.	98.36	0.14	1.40	0.12	0.05
558	9-11 ft.	98.56	0.26	1.36	0.13	0.06
559	11-13 ft.	98.17	0.33	0.95	0.17	0.07
560	13-15 ft.	98.20	0.27	1.46	0.17	0.07
561	15-17 ft.	98.63	0.20	1.34	0.16	0.04
562	17-19 ft.	98.67	0.16	1.22	0.19	0.05
563	19-21 ft.	98.70	0.17	1.08	0.16	0.05
564	21-23 ft.	98.78	0.18	1.02	0.16	0.05
565	23-25 ft.	98.57	0.15	1.21	0.20	0.05
566	25-27 ft.	98.93	0.13	0.83	0.11	0.05
567	27-29 ft.	98.79	0.19	0.91	0.14	0.07
568	29-31 ft.	98.84	0.30	0.79	0.12	0.05
569	31-33 ft.	98.88	0.39	0.72	0.13	0.08
570	33-35 ft.	98.82	0.31	0.87	0.11	0.06
571	35-37 ft.	98.52	0.40	0.98	0.20	0.08
572	37-39 ft.	98.48	0.37	0.87	0.20	0.07
573	39-41 ft.	98.29	0.57	0.98	0.27	0.08
574	41-43 ft.	98.78	0.24	0.85	0.16	0.07
575	43-45 ft.	98.61	0.44	0.79	0.16	0.07
576	45-47 ft.	98.46	0.44	0.85	0.15	0.07
577	47-49 ft.	98.17	0.36	1.32	0.15	0.06
578	49-51 ft.	98.34	0.21	1.25	0.10	0.07
579	51-53 ft.	98.20	0.33	1.31	0.14	0.08
580	53-55 ft.	98.46	0.22	1.17	0.18	0.06
581	55-57 ft.	98.21	0.47	0.95	0.14	0.05
582	57-59 ft.	96.65	0.41	2.72	0.19	0.07
583	59-61 ft.	90.85	0.60	8.02	0.28	0.08
584	61-63 ft.	97.81	0.32	0.91	0.16	0.07
585	63-65 ft.	97.81	0.39	0.98	0.21	0.08
586	65-67 ft.	98.26	0.25	1.28	0.17	0.07
587	67-69 ft.	97.99	0.24	1.70	0.10	0.07
588	69-71 ft.	98.12	0.35	1.57	0.14	0.06
589	71-73 ft.	98.48	0.30	0.91	0.13	0.06
590	73-75 ft.	97.86	0.34	1.36	0.12	0.06
591	75-77 ft.	98.48	0.31	1.13	0.15	0.06
592	77-79 ft.	98.12	0.31	1.24	0.15	0.06
593	79-84 ft.	97.85	0.38	1.51	0.15	0.06
594	84-86 ft.	92.23	0.16	6.88	0.19	0.06
595	86-88 ft.	91.34	0.14	7.91	0.21	0.05
596	88-90 ft.	94.55	0.11	4.65	0.13	0.04
597	90′ 5″-102′ 6″	86.43	0.75	12.14	0.34	0.17
598	Average 84′	98.14	0.33	1.16	0.16	0.06
599	Average 90′	97.77	0.31	1.51	0.16	0.06

Shot Drill Hole No. 11.

Elevation 90 ft. above Lake Huron.

No. of Anal.	Depth.	$CaCO_3$.	SiO_2.	$MgCO_3$.	$FeAl_2O_3$.	$CaSO_4$.
600	0-4′ 6″	97.20	0.49	1.46	0.62	trace
601	4′ 6″-8′ 6″	98.18	0.30	1.47	0.33	trace
602	8′ 6″-12 ft	98.45	0.30	1.13	0.40	0.09
603	12-15 ft	98.34	0.11	1.19	0.27	0.09
604	15-18 ft	97.80	0.38	1.34	0.31	trace
605	18-20 ft	98.25	0.29	1.13	0.12	trace
606	20-24 ft	98.03	0.22	1.78	0.20	0.09
607	24-28 ft	96.11	0.45	2.50	0.41	0.23
608	28-32 ft	91.64	0.30	7.87	0.36	0.27
609	32-37 ft	96.11	0.32	3.34	0.33	0.29
610	37-40 ft	95.61	0.25	3.97	0.34	0.35
611	40-44 ft	97.82	0.28	2.19	0.34	0.12
612	44-56 ft	96.80	0.41	2.16	0.42	trace
613	56-60 ft	97.80	0.22	2.04	0.43	0.07
614	60-63 ft	95.35	0.33	3.82	0.33	0.09
615	77-79 ft	98.03	0.18	1.76	0.50	0.05
616	Average	96.79	0.32	2.48	0.35	....
617	79-85 ft	62.58	0.37	38.02	0.50	....

SHOT DRILL HOLE NO. 12.

Property of Michigan Limestone and Chemical Co.

Near section line about 1600′ W., S. E. cor. Sec. 23, T. 35 N., R. 5 E.

Elevation 100 ft. above Lake Huron.

Number of analysis.	Depth.	$CaCO_3$.	SiO_2.	$MgCO_3$.	$FeAl_2O_3$.	$CaSO_4$.
618	0- 4 ft.	97.99	0.27	2.07	0.37	trace
619	4- 6 ft.	98.38	0.42	1.23	0.29	trace
620	6- 8 ft.	97.81	0.32	2.49	0.11	trace
621	8-10 ft.	98.38	0.31	1.65	0.27	trace
622	10-12 ft.	98.10	0.37	1.23	0.13	trace
623	12-14 ft.	97.81	0.35	2.49	0.22	trace
624	14-16 ft.	97.02	0.59	2.49	0.41	trace
625	16-18 ft.	98.24	0.14	2.07	0.24	trace
626	18-20 ft.	97.10	0.14	2.30	0.14	trace
627	20-22 ft.	96.61	0.19	2.10	0.19	trace
628	22-24 ft.	96.61	0.11	2.30	0.11	trace
629	24-26 ft.	98.90	0.11	2.10	0.11	trace
630	26-28 ft.	97.70	0.10	2.10	0.10	trace
631	28-30 ft.	97.01	0.31	2.32	0.31	trace
632	30-32 ft.	97.70	0.24	2.52	0.24	trace
633	32-34 ft.	97.10	0.32	2.73	0.32	trace
634	34-36 ft.	97.10	0.41	1.57	0.74	trace
635	36-38 ft.	97.60	0.35	1.89	0.52	trace
636	38-40 ft.	97.60	0.31	1.47	0.48	trace
637	40-42 ft.	98.10	0.26	1.47	0.46	trace
638	42-44 ft.	98.45	0.28	0.52	0.35	trace
639	44-46 ft.	97.75	0.24	1.26	0.39	trace
640	46-48 ft.	97.45	0.26	1.68	0.52	trace
650	48-50 ft.	97.85	0.23	1.47	0.55	trace
651	50-52 ft.	95.87	0.42	3.16	0.27	0.27
652	52-54 ft.	96.12	0.29	2.09	0.25	0.33
653	54-56 ft.	96.37	0.20	2.72	0.33	0.13
654	56-58 ft.	94.25	0.11	1.88	4.56	0.07
655	58-60 ft.	96.12	0.26	1.88	0.35	0.25
656	60-62 ft.	96.12	0.25	1.88	0.25	0.29
657	62-66 ft.	97.60	0.25	1.67	0.22	0.16
658	66-79 ft.	92.62	0.33	5.87	0.25	0.25
659	70-74 ft.	97.11	0.42	1.89	1.00	trace
660	74-78 ft.	92.13	0.35	6.51	0.80	trace
661	78-80 ft.	91.13	0.08	5.25	3.94	trace
662	80-84 ft.	97.61	0.05	1.68	1.30	trace
663	84-88 ft.	92.88	0.18	4.20	1.50	trace
664	88-92 ft.	92.62	0.37	4.83	1.17	trace
665	Average 60-92′.	94.53	0.26	3.77	1.04	0.06
666	Average 92′.	96.32	0.27	2.59	0.64	0.044
667	Average 92-100′.	65.99	0.34	33.40	1.16	....

The amount of magnesian limestone above the basal beds, however, is insignificant as compared with the amount of high calcium limestone, and does not appreciably affect the average composition of the quarry product. According to Mr. Bradley, the average of cargo analyses (Anal. No. 465) for 1914 gave 97.38 per cent of calcium carbonate and only 1.81 per cent of magnesium carbonate. The above core analyses (Nos. 469-667) show the exceptional purity of the Dundee

limestone in the vicinity of Rogers City. Analyses of cores from a number of relatively shallow holes gave similar results.

Exposures of the Dundee limestone occur at several points along the lake for fifteen miles eastward from the Calcite quarry. The most important are in the vicinity of Adams Point. Exposures also occur near Thompsons Harbor. The extent of the areas of Dundee limestone under thin drift cover, however, has not been fully determined in the region east of Calcite.

The exceptionally high average content of calcium carbonate and the low content of silica make the Dundee limestone in the vicinity of Rogers City especially adapted for flux and for general use in the chemical industries.

Traverse Formation.

Long Lake Series.

Exposures of the Long Lake or Lower Traverse series are very large and numerous in the northern part of the county where they commonly occur in the form of prominent bluffs, ridges and hills. A discontinuous line of bluffs extends from sec. 6, T. 33 N., R. 8 E., on the west side of Grand Lake, northwest through sections 19 and 20, T. 34 N., R. 7 E., to the vicinity of Liske, sec. 16, T. 34 N., R. 6 E. Apparently this line of bluffs reappears about 3 miles south of Rogers. A parallel line of bluffs extends from section 10, T. 33 N., R. 7 E., northwest of Long Lake toward Hagensville. Detached areas of the Long Lake series occur on the east side of Grand Lake. Some of the beds are very pure but the series is more or less argillaceous and bituminous and contains seams and beds of shale and magnesian limestone. Development of exposures of Long Lake limestones should be preceded by careful testing with the drill.

Limestone is exposed in a gorge of the East Branch of Rainy river, (S. E. ¼ sec. 26, T. 35 N., R. 2 E.) and is near the surface over a considerable area adjacent. The section exposed is as follows:

Section on E. Branch of Rainy river.

		Thickness, feet.
1.	Gray fossiliferous limestone containing numerous Atrypa and Gypidulas	2
2.	Very dark bituminous and fossiliferous limestone with an abundance of Acervularia, Stromatopora, and crinoid stems	3
3.	Dark gray crystalline limestone	4
4.	Gray argillaceous and fossiliferous limestone with many Atrypa and Gypidulas.	2+

An analysis of a set of samples from this exposure gave 92.97 per cent of calcium carbonate, 2.84 per cent of silica, 1.65 per cent of iron and alumina, and 2.27 per cent of magnesium carbonate.

Dark gray crystalline and bituminous limestone is also exposed a half mile north at the falls of Rainy river back of the schoolhouse in sec. 25.

At the falls of the Ocqueoc river in S. W. ¼, S. E. ¼, sec. 22, T. 35 N., R. 3 E., the following section is exposed:

Section at Ocqueoc Falls.

No. of bed.		Thickness, feet.
1.	Gray crystalline magnesium limestone	6
2.	A mass of cup corals and Stromatopora in a matrix of dark bituminous limestone	1
3.	Massive dark crystalline and bituminous magnesium limestone	3½
4.	Banded dark bituminous and crystalline magnesium limestone with Acervularia near the top	4
5.	Banded dark bituminous and mottled and streaked magnesium limestone with numerous cavities, very fossiliferous in the upper portion	8

An analysis of a set of samples from the section gave 34.74 per cent of magnesium carbonate. The very bituminous and magnesian character of the limestone apparently makes it of little economic value.

Grand Lake. A bluff of limestone about 40 feet in height occurs on the west side of Grand Lake in N. E. ¼ sec. 6, T. 33 N., R. 8 E. The following section is exposed:

		Thickness, feet.
	Drift	0–2 +
1.	Dark bituminous and fossiliferous limestone with crinoid stems, acervularia, and brachiopods	2½
2.	Gray to dark bituminous limestone with scattered corals and crinoid stems	6
3.	Dark beds of bituminous limestone alternating with seams of coral, Stromatopora	10
4.	Talus	15 +

The lower part of the bluff is covered with talus but according to reports shale was struck in a core drilling at 35 feet. The thickness of the shale is unknown but the Bell shale forms the floor of the deeper portions of the lake.

Core drillings put down east of Thompson's harbor in secs. 11, 12, 13, and 14, T. 34 N., R. 7 E., penetrated more or less magnesian limestone. Shale, apparently the Bell, was struck at shallow depths in a number of core drillings near the south end of Grand Lake in sec. 11, T. 33 N., R. 8 E.

Alpena Limestone.

The exposures of the Alpena limestone are large and very numerous from the south end of Black Lake southeast into Alpena county. A series of limestone ridges cross the road from Onaway north to Black Lake. The upper beds are generally gray, crystalline and fossiliferous with some very dark bituminous beds. The lower beds, as exposed in

Black Lake quarry (see Cheboygan county), are light gray, fine grained to lithographic limestone, locally with small disseminated calcite crystals. A nearly continuous bluff extends from Black Lake for several miles along the south bank of Rainy river.

Numerous exposures also occur in the vicinity of Posen. Their character has not been carefully investigated but most of the limestone is high calcium and probably of commerical grade.

Summary. Presque Isle county has large limestone resources but they have been carefully investigated, only in the vicinity of Rogers City, Black Lake, Thompsons Harbor, and on the east and west sides of Grand Lake. The exposure of the Dundee limestone at Rogers City is the largest, purest and most important of any in the state.

Schoolcraft County.

Distribution. The Engadine dolomite underlies the extreme southeastern part of Schoolcraft county along the shore of Lake Michigan. The Manistique series forms a belt extending from Garden Peninsula E-NE across the county. The Fiborn limestone and the Hendricks series form successive belts north of the Manistique series. The Cincinnati shales and the Trenton limestone cross the northern and northwestern parts of the county.

Exposures of limestone are very large and numerous in the southern part and rock is thinly drift covered over large areas. The exposures of the Engadine dolomite are usually in the form of bold cliffs. Those of the Manistique series are in a succession of ridges and small escarpments usually extending in a general E-W direction. At or near the northern limit, the series terminates in bluffs 20 to 90 feet in height. The Fiborn limestone is exposed over an area of two or three square miles in the eastern part of the county but westward it is drift covered. The Hendricks series lies almost wholly within the area of deep drift in the northern and western portions of the county.

Quarries and Localities.

Engadine dolomite.

Mouth of Bull Dog river. Massive beds of Engadine dolomite are exposed in bluffs near the mouth of Bull Dog river and form the lake bottom for a considerable distance off shore. The dolomite is very massive, crystalline and bluish white with mottlings and streaks of blue where fresh. Where altered the mottlings have become yellow

and brown. The crystalline character and bluish colorations led to considerable core drilling near the mouth of the river a number of years ago in an attempt to prove up a marble deposit.

The dolomite probably would make common building stone. The color is not permanent. Exposure to the weather for a few years is generally sufficient to alter the color to white, yellow, or brown.

Bluffs of Engadine dolomite occur on Seoul Choix Pt. and north of McDonald and Gulliver lakes. The bluff north of the lakes is near the Minneapolis, St. Paul & Ste. Marie Railroad.

Manistique. The Manistique series is exposed in the bed of Manistique river in a bluff in the eastern part of Manistique and at many places northwest from Manistique to "Big Hill" bluff in secs. 21 and 22, T. 42 N., R. 16 W., a distance of about five miles. The name of the series was taken by the writer from Manistique because of the numerous exposures in its vicinity.

Manistique quarry. The White Marble Lime Co. has operated a quarry in the bluff in the eastern part of Manistique for many years. Quarrying began near the south end of the bluff in very cherty limestone. Later operations were begun farther north where these beds are absent. The section exposed in the old and new quarries is as follows:

Section in Manistique quarries.

	Old quarries.	Thickness, feet.
	Sand and gravel	0-3
1.	Light buff crystalline, thin bedded magnesian limestone with many seams of chert nodules 2 to 6 inches in thickness	9-12
2.	Light buff massive magnesian limestone	1 8 in.
3.	Light buff crystalline, thin bedded and magnesian limestone with many nearly continuous seams of chert	8
	New quarry.	
4.	Hard bluish dense grained well bedded dolomite used chiefly for road material, concrete, and railroad ballast	10 6 in.
5.	Soft yellowish to white limestone very free from impurities. Used for burning lime	1 8 in.
6.	Light yellowish to buff cherty limestone similar to beds Nos. 1 and 3, but thicker bedded. Used for burning lime. The chert is chiefly in two beds and is readily sorted out	7 6 in.
7.	Hard, very massive bluish and fine grained dolomite. Used chiefly for road making, concrete, etc	4 6 in.
8.	Buff crystalline magnesian limestone with some chert and dense cavities. Used for burning lime	8

Experience has shown that the bluish dense grained dolomites generally burn hard and that the light colored crystalline and fossiliferous limestones burn easily.

The stone is blasted down, loaded by hand, and trammed by horse power to the foot of an incline where it is hauled to the crushing plant by cable. The better quality of stone is burned for magnesian lime

and the inferior is used for road making, concrete and railroad ballast. Much of the stone for lime burning is obtained from other quarries operated by the company.

All of the beds are either dolomite or high magnesian limestone. Analysis No. 671 and probably No. 672 are from the upper blue dolomite in the new quarry, Nos. 673-4 from the beds (Nos. 5, 6, and 8) burned for lime.

Marblehead quarry. Marblehead quarry is located about 6 miles northeast of Manistique in S. E. ¼ sec. 35, T. 42 N., R. 15 W. The quarry is opened along the southeastern side and near the top of a ridge. The workings at the time of the writer's visit (1913) were about 2000 feet long and the face about 8 feet in height. The beds are bluish and very crystalline and resemble the Engadine dolomite. The floor of the quarry is composed of soft yellowish, earthy, fossiliferous and very cherty limestone. It is locally termed "rotten" limestone and is of little value for any purpose.

The upper bed is a pure dolomite as shown by analyses Nos. 675-679. It is burned for lime and is adapted for paper manufacture.

A bluish dense grained dolomite forms the cap rock on a hill about 40 rods east of Marblehead quarry and is underlain by a light yellowish, cherty, "rotten" limestone as in the Marblehead quarry. The blue dolomite is quite different in physical qualities from that in the latter quarry. It can not be satisfactorily burned for lime.

For several miles north and east from Marblehead ridges of limestone are exposed in the fields and in road cuts. The exposures show the same alternating series of bluish, fine grained dolomites and white or light buff, crystalline, magnesian limestones, locally very cherty and fossiliferous as at Manistique. The northern edge of this area of exposures terminates in a line of bluffs on the south side of Manistique river.

"Ninety-foot" Bluff. The highest portion of this line of bluffs is in sec. 8, T. 42 N., R. 14 W., and is locally called the "Ninety-foot" bluff. The section exposed is as follows:

Section at "Ninety-foot" Bluff.

		Thickness, feet.
	Surface	0-1 +
1.	Light colored coarsely crystalline magnesian limestone. Thickness not determinable because of talus	4 ±
2.	Light buff porous, finely crystalline magnesian limestone	6 +
3.	Light buff porous finely crystalline magnesian limestone similar to bed No. 2	12 ±
4.	Hard light buff gray densely crystalline and delicately banded dolomite, breaking with a smooth conchoidal fracture	6 ±
5.	Buff gray nodular and fossiliferous limestone, containing cup corals, favosites	5
6.	Light buff finely crystalline magnesian limestone	8 +

The lower 30 or 35 feet of the bluff is concealed by talus.

Similar but higher beds are exposed in another bluff called the "Sixty-Foot" bluff near the west quarter post of section 9, T. 42 N., R. 14 W. Analysis No. 700 is from white crystalline dolomite at the top, No. 701 from thin-bedded, light gray, crystalline dolomite 20 feet below, and No. 702 from light gray massive crystalline, dolomite 30 feet from the top. The lower 30 feet of the bluff is drift covered.

"Big Hill" Bluff. "Big Hill" bluff extends through secs. 14 and 15, T. 42 N., R. 16 W., and forms the northern limit of exposures of the Manistique series in this township. The following section was exposed:

Section at "Big Hill" Bluff.

		Thickness, feet.
	Surface	0–6+
1.	Hard brittle white to light buff finely crystalline magnesian limestone	2–6
2.	Buff crystalline limestone having a sugary appearance. Lower part of bed concealed by talus	8+
3.	Hard buff gray, densely crystalline, thin bedded dolomite with a smooth conchoidal fracture	6
4.	Buff nodular magnesian limestone with fossils, coral and drusy cavities. Bed partially concealed by talus	8 ±
5.	Hard brittle buff gray thin-bedded, densely crystalline dolomite	7 ±
6.	Hard buff thin-bedded, densely crystalline limestone with a smooth conchoidal fracture. The centre of the bed was concealed by talus	14 ±
7.	Soft crystalline magnesian limestone resembling brown sugar	3
8.	Buff earthy to crystalline magnesian limestone with druse cavities and fossils, chiefly corals. Weathers to a nodular mass	5
9.	Hard gray, porous crystalline and laminated magnesian limestone	8+

The lower 25 feet of the bluff is drift covered.

Cooks Station. Similar facies of magnesian limestone and dolomite are exposed at many places for several miles northeast of Cooks Station. Formerly lime was burned in this locality. The stone used was from the densely crystalline beds and was said to burn hard.

Analysis No. 698 is from the upper, densely crystalline, beds used for burning lime and No. 699 from the underlying white, coarsely crystalline beds.

A quarry was opened for local building purposes in a low bluff near the center of sec. 28, T. 42 N., R. 17 W. The section exposed was as follows:

		Thickness, feet.
	Surface	0–6+
1.	Cherty very fossiliferous (cup corals) limestone	2
2.	Hard buff gray finely crystalline limestone with some fossils in the upper part and many fossils, chiefly cup corals and Stromatopora in the lower part	2½
3.	Hard buff gray finely to densely crystalline and very fossiliferous (cup corals) limestone	1+

Limestone is exposed at many places in the northeastern part of Garden Peninsula. The beds are similar in general character to those on the west shore of the peninsula (see Delta County.)

Fiborn Limestone.

Blaney quarry. The White Marble Lime Co. of Manistique operates a quarry located in section 3, T. 42 N., R. 13 W., on the Blaney and Southeastern Railroad. It is near the west end of low flat ridge of Fiborn limestone, nearly a mile in width. The ridge extends eastward through sections 1 and 2 into Mackinac county. The overburden is absent or very thin over much of the area. This is the largest area of Fiborn limestone under thin drift cover in the state.

The Fiborn limestone in the Blaney quarry has a maximum thickness of 26 feet. The stone is poorly bedded. It is gray to buff, very brittle, dense grained to lithographic, high calcium limestone, with a smooth conchoidal fracture, and containing numerous small crystals of calcite. The content of calcium carbonate generally is between 95 and 98 per cent (Anal. Nos. 680-8) and the magnesium carbonate between 1 and 2 per cent. Locally the basal portion of the bed contains more than 2 per cent of calcium carbonate.

The floor of the quarry is a white, coarsely crystalline, heavy magnesian (Anal. No. 689) limestone.

Analyses Nos. 690-1 are from a ridge about 4 feet in height in the S. W. ¼, S. W. ¼ sec. 1, and Nos. 692-3 from a cave near the center of this section.

Whitedale. A small exposure of buff to gray fine grained to lithographic, high calcium limestone occurs about five miles north of Whitedale in the road 40 rods west of the N. E. cor. of sec. 11, T. 42 N., R. 14 W. It is similar in every respect to the Fiborn limestone. Small exposures occur in the fields adjacent. The bed is overlapped on the south by gray, crystalline dolomite of the Manistique series which is exposed at a higher level in the fields and in a shallow quarry about 60 rods southeast. The exposures are only a few feet above the level of a swamp and apparently the area of this stone under favorable quarrying conditions is small. An analysis (No. 695) of a hand specimen of the buff lithographic limestone gave 55.35 per cent of calcium oxide and only 1.24 per cent of magnesian oxide.

Several small quarries have been opened north of Whitedale by the local highway officials for road material. The largest of these is in a ridge in the S. E. ¼ sec. 6, T. 42 N., R. 13 E. The quarry is about 14 feet in depth. The beds here are white crystalline limestone. The top stratum is poorly bedded but the lower ones are well bedded. The bottom bed is laminated. The area of quarryable stone could not be ascertained because of heavy timber.

The beds resemble the white crystalline low magnesian beds below

the Fiborn limestone in Hendricks quarry, Mackinac county. Analysis No. 696 is of a composite sample from the upper 8 feet and No. 697 of the laminated portion at the bottom.

Summary. Schoolcraft has almost inexhaustible reserves of high magnesian limestone and dolomite. It also has very large reserves of high calcium limestone in the eastern part of the county.

Wayne County.

Distribution. The Dundee limestone occupies that portion of Wayne county south of a line drawn from Detroit southwest to the southwestern corner of the county with the exception of a small area in the southeastern corner which is underlain by the Monroe formation. There are only a few exposures, most of the county being heavily drift covered.

Quarries and Localities.

Monroe Formation.

Gibralter quarry. A knoll of Upper Monroe dolomite occurs about a mile northeast of Gibralter in sec. 35, T. 4 S., R. 10 E. For a number of years a quarry was operated at this place for building stone, road material, concrete, and railroad ballast. The quarry is about 20 feet* in depth but was full of water at the time of the writer's visit in 1913. According to Lane† all but the upper bed contain crystals of strontium sulphate. They are similar in general character to the Upper Monroe beds in Monroe county as shown by analyses Nos. 703 to 706.

Formerly a quarry was operated near the south end of Grosse Isle. Exposures also occur on Stony Island. A large amount of dolomite from the Upper Monroe series has been removed from Detroit river at Lime Kiln Crossing by the United States government in deepening the river channel. Stone companies utilize this stone for road making, concrete and railroad ballast.

Dundee limestone.

Sibley quarry. A knoll of Dundee limestone occurs at Sibley. This is the only exposure of the Dundee in Wayne county. A large quarry is operated at this place by the Solvay Process Co. of Detroit. The section‡ exposed in the quarry is as follows:

*W. H. Shuzer and A. W. Grabau, The Monroe Formation, Pub. 2, Geol. Ser., p. 52, Mich. Geol. & Biol. Surv., 1909.
†A. C. Lane, Ann. Rept.
‡W. H. Sherzer, Geology of Wayne Co. Pub. 12 Geol. Ser. 9, p. 202 Mich. Geol & Biol. Surv. 1911.

Section in Sibley quarry.

		Thickness, feet.
1.	Yellow brown to gray thin bedded and very fossiliferous limestone ($CaCO_3$, 91%; MgCO, 2.52%; Anal. No. 707)	6
2.	Thin bedded gray to bluish limestone ($CaCO_3$, 92%; $MgCO_3$, 4.62%; Anal. No. 708)	7
3.	Compact gray very fossiliferous limestone ($CaCO_3$, 94.50%; $MgCO_3$, 3.36%; Anal. No. 709)	2
4.	Compact crystalline limestone, bluish where weathered	5
5.	Compact gray to blue fossiliferous limestone ($CaCO_3$, 87%; $MgCO_3$, 9.45%; Anal. No. 711)	6
6.	Brittle bluish gray cherty limestone with some fossils. Locally termed the "14-inch flint" bed	1 2 in.
7.	Gray to bluish limestone, more heavily bedded ($CaCO_3$, 85.75%; $MgCO_3$, 10.29%; Anal. No. 712)	6
8.	Very brittle impure chert with some fossils (SiO_2, 30.87%; Anal. No. 713)	2
9.	Compact heavily bedded blue to gray fossiliferous limestone ($CaCO_3$, 93.50%; $MgCO_3$, 2.73%; Anal. No. 714)	9
10.	Oily compact heavily bedded blue to gray magnesian limestone. Less fossiliferous than No. 9. Locally called the "6-foot magnesian" bed ($CaCO_3$, 74%; $MgCO_3$, 20.58%; Anal. No. 715)	6
11.	Thin bedded gray fossiliferous limestone ($CaCO_3$, 87%; $MgCO_3$, 9.66%; Anal. No. 716)	8
12.	Light to dark gray fossiliferous and magnesian limestone "12-foot lower magnesian" bed	12
13.	Thin bedded siliceous limestone, poor in fossils	7

Two core drillings were made at Sibley quarry. The following analyses are of the core from the drilling on the west side of the quarry where beds No. 1 to 8 inclusive are absent.

Analysis of drill core, hole No. 2, Sibley quarry.

Number of analysis.	Depth, feet.	Silica. SiO_2.	Iron-Alumina. Fe_2O_3-Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
725	0- 5	1.98	1.67	87.63	49.11	8.72	4.17	Bed 9. Quarry beds 1-8 not represented in hole.
726	5-10	1.90	1.82	87.26	48.90	9.02	4.31	Bed 10.
727	10-16	2.78	1.67	83.99	47.07	11.56	5.53	Bed 11.
728	16-20	2.39	1.89	81.08	45.44	14.63	6.99	Bed 11.
729	20-25	0.73	1.19	93.26	52.26	4.82	2.30	Fossils.
730	25-27	2.21	1.96	81.81	45.84	14.02	6.70	
731	27-33	8.16	0.72	75.99	42.58	15.13	7.23	
732	33-35	7.24	0.99	82.72	46.35	9.06	4.33	
733	35-40	2.63	0.66	92.54	92.54	4.17	1.99	Base of Dundee.
734	40-42	9.50	0.22	87.79	49.20	2.49	1.19	
735	42-45	2.89	1.57	79.99	44.82	15.45	7.39	
736	45-48	4.95	0.06	87.08	48.80	7.91	3.78	Anderdon.
737	48-53	1.50	6.50	68.38	38.32	23.64	11.30	
738	53-55	0.96	5.01	70.54	39.53	23.49	11.23	Differences mainly alumina, iron, and organic matter.
739	55-58	0.54	3.76	59.99	33.63	35.70	17.07	
740	38-62	0.49	2.21	64.72	36.27	32.57	15.58	
741	62-65	0.29	4.01	62.36	34.94	33.34	19.94	
742	65-70	0.68	2.87	59.45	28.51	37.00	17.19	Flat Rock (?)
743	70-78	0.22	2.54	54.27	30.41	43.04	......	
744	78-80	1.05	1.92	59.15	33.15	37.88	18.12	
745	80-83	0.31	0.56	58.09	32.55	40.04	19.15	

A large amount of stone has been removed. Most of the thinly drift covered area has been quarried and the overburden—locally is becoming very heavy.

The high calcium stone is used largely in the manufacture of soda ash and related products. It is also used for sugar and paper manufacture, flux, and agricultural purposes. The more magnesian and impure stone is used for concrete, road making, and railroad ballast.

Summary. The Dundee limestone at Sibley quarry is the only exposure of high calcium limestone in Wayne county. The areas of Upper Monroe dolomite under thin drift are small and of little commercial importance at present.

Analyses[1] of Michigan

ALGER

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
19	Near Chatham, Alger Co.	Calciferous sandstone.	Hand specimen......	Mich. Agri. Coll. Exp. Station.
20	Mud Lake 3 mi. S. of Autrain River falls.	Sandy dolomite......	Hand specimen......	*Rominger..........
21	Falls of Autrain	Sandy dolomite......	Hand specimen......	*Rominger..........
22	Coaling Sta. No. 3 of Munising Furnace, Grand Island Bay,	Slightly sandy dolomite. Top strata on hills.	Hand specimen......	*Rominger..........
23	Near Munising Furnace, Gd. Island Bay,	Dolomite with some sand. Top of ravine near furnace.	Hand specimen......	*Rominger..........

*Vol. I, Pt. III, p. 78, Mich. Geol. Surv.

ALPENA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
24	Rockport quarry, Great Lakes Stone & Lime Co.,	Rockport limestone. Quarry beds from top to bottom. Dark bituminous limestone filled with white masses of coral, stromatopora, etc.	Composite of hand specimens.	R. C. Banks, Univ. of Mich. Lab., 1915.
25	Same as above.	Representative sample of entire quarry.	Same as above.......	Diamond Alkali Co...
26	Same as above.	Same as above.......	Same as above.......	Geo. F. Harris, Mich. Limestone & Chemical Co.
27	Same as above.	Near floor of quarry..	Same as above.......	Same as above.......
28	Same as above.	Near top of bluff.....	Same as above.......	Same as above.......
29	Same as above.	Carbonaceous matter in seams and around fossils.	Same as above.......	Same as above.......
30	Michigan Alkali Co. quarry, sec. 13, T. 31 N., R. 8 E.	Upper beds Nos. 1 and 2 S. E. side of quarry. Hard buff crystalline limestone 8 ft. thick.	Composite of hand specimens taken at top and bottom of beds.	R. C. Banks, Lab. Univ. of Mich. 1915.
31	Same as above.	Bed No. 3. Hard grayish buff crystalline limestone with bituminous streaks; 9 ft. thick.	Composite of hand specimens 1 ft. apart.	Same as above.......
32	Same as above.	Bed No. 5. Dark gray crystalline limestone with bituminous streaks; 4 ft. thick.	Same as above.......	Same as above.......

[1]Figures in italics calculated from original analyses.

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
35.00	5.00		32.00	*17.93*	22.00	*10.52*	......	Water and organic matter 6 per cent.
†23.00	0.70		42.00	*23.54*	34.00	*16.26*	......	Residue siliceous, finer comminuted dust.
†15.00	2.00		47.00	*26.34*	36.00	*17.22*	......	Residue of quartz sand.
†3.70	4.00		53.00	*29.70*	39.00	*18.66*	......	Residue of quartz sand.
†6.00	5.00		49.00	*27.46*	40.00	*19.13*	......	Residue of quartz sand.

†Insoluble in HCl.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
0.19	‡0.77		97.25	*54.50*	1.84	*0.88*	......	Samples collected by R. A. Smith, Mich. Geol. Surv., 1914.
1.18	1.05		94.75	*53.10*	1.55	*0.74*	......	Collected by Mr. Marsters.
1.51	1.08		93.50	52.36	3.90	1.86	Org + H_2O 1.47	Collected by Mr. Marsters.
0.54	1.07		95.73	53.61	2.65	1.27	......	
0.86	1.51		95.50	53.48	2.12	1.01	......	Collected by Mr. Hollister.
......	....		......	......	......	......	......	Volatile matter 20.50 per cent. Combustible matter 22.80 per cent
0.41	*0.90		90.43	*50.68*	8.31	*3.97*	......	Samples taken by R. A. Smith, Mich. Geol. Surv., 1914.
1.13	*0.75		94.54	*52.98*	2.61	*1.25*	......	Same as above.
4.03	*1.78		92.38	*51.77*	1.80	*.86*	......	Same as above.

*R_2O_3=Iron, alumina, etc.

Analysis[1] *of Michigan*

ALPENA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
33	Same as No. 30.	Bed No. 7. Light buff crystalline limestone 3 ft. thick.	Same as above	Same as above
34	Same as above.	Beds Nos. 9 and 10. Grayish buff to buff crystalline limestone 8 ft. thick. Lowest beds in upper quarry.	Same as above	Same as above
35	Same as above.	Lower quarry beds, Nos. 11 to 14 inc. Dark massive, crystalline & fossiliferous limestones, 28 ft. thick.	Composite of hand specimens.	Same as above
36	Same as above.	Different beds in quarry.	Hand specimen	H. H Hindshaw
37	Same as above.		Hand specimen	H. H. Hindshaw
38	Same as above.		Hand specimen	H. H. Hindshaw
39	Same as above.		Hand specimen	H. H. Hindshaw
40	Same as above.		Hand specimen	H. H. Hindshaw
41	Same as above.		Hand specimen	H. H. Hindshaw
42	El Cajon Ptld. Cem. Co., quarry, El Cajon Beach, sec. 10, T. 32 N. R. 9 E.	Long Lake beds. Shaly fossiliferous (brachiopods) limestones. 3 beds, 6 ft. section in quarry.	3 hand specimens	R. C. Banks, Lab., Univ. of Mich., 1915.
43	Alpena Portland Cement Co. quarries, Alpena.	Compact limestone from quarry opposite cement plant.	Hand specimen	*F. Brady, Illinois Steel Co.
44	Same as above.	Fragment of Favosites with cavities filled by infiltration.	Hand specimen	Same as above
45	Same as above.	Quarry beds	Hand specimen	*S. H. Ludlow, Alpena Ptld. Cem. Co.
46	Same as above.		Hand specimen	Same as above
47	Same as above.	Bluish coralline limestone with a flinty texture.	Same as above	Same as above
48	Same as above.	"Sugar stone"	Hand specimen	Same as above
49	Same as above.	Reef of coral limestone.	Hand specimen	Same as above
50	Same as above.	Lower part of Alpena limestone. Sample from well of cement company, depth 32 ft.	Hand specimen	Same as above
51	From Alpena quarries.	Traverse limestone, quarry product as shipped to Alma Sugar Co.	Composite sample from car lots.	†A. N. Clark, Alma Sugar Co., 1902.
52	Alpena Ptld. Cement Co.	Alpena limestone, quarry beds and beds penetrated in a well near plant.		‡W. H. Sherzer

[1]Figures in italics calculated from original analyses.

limestones by counties.—Con.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.		Remarks.
1.46	*0.75		95.58	*53.56*	2.11	*1.01*	......	......	Same as above.
2.09	*0.66		94.78	*53.12*	2.45	*1.17*	......	......	Same as above.
1.05	*1.02		96.40	*54.03*	1.52	*.73*	......	......	Same as above.
							$CaSO_4$		
0.61	0.28		93.15	*52.20*	3.72	*1.77*	None		
7.05	2.97		84.95	*47.61*	1.82	*.87*	0.09	......	Sample taken by H. H. Hindshaw.
3.63	1.07		90.96	*50.98*	2.09	*1.00*	0.07	......	Same as above.
6.51	1.50		87.79	*49.20*	2.38	*1.14*	0.07	......	Same as above.
0.91	0.32		97.59	*54.69*	1.42	*.68*	trace	......	Same as above.
0.48	0.30		97.14	*54.44*	2.10	*1.00*	trace	......	Same as above.
32.85	6.27		59.00	*33.06*	1.92	*.92*	......	......	Samples by R. A. Smith, Mich. Geol. Survey, 1914.
							S.	P_2O_5.	
0.70	0.30	0.76	96.90	*54.30*	1.30	*0.62*	0.022	0.020	Samples collected by A. W. Grabau, 1901.
0.38	0.19	0.21	98.69	*55.30*	0.52	*0.24*	0.009	0.004	
0.32	0.55		98.23	*55.05*	0.98	*0.47*	......	......	
	0.73		95.16	*53.33*	3.91	*1.87*	......	......	SiO_2 included in Fe_2O_3—Al_2O_3.
	0.34		98.62	*55.27*	1.04	*0.50*	......	......	
......	......	......	98.32	*55.10*	......	......	......	......	
0.21	......	0.33	99.33	*55.67*	0.21	*0.10*	......	......	Large blast of limestone. A later blast analyzed 99.63 $CaCO_3$.
0.40	1.00		97.16	*55.45*	1.06	*0.50*	......	......	
	1.30		97.60	*54.70*	1.09	*0.52*	......	......	SiO_2 included in Fe_2O_3—Al_2O_3.
0.33 to 1.77	0.13 to 1.21		89.10 to 98.37	*49.93* to *55.13*	0.92 to 8.67	*0.44* to *4.14*	......	......	Range in composition of quarry beds.

*R_2O_3=iron, alumina, etc.

Analyses of Michigan*

ALPENA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
54	Alpena Ptld. Cement Co., quarries, sec. 18, T. 31 N., R. 9 E.	Top shell; removed in stripping; 1 to 2 ft. thick.	Hand specimen......	*F. M. Haldeman, 1900.
55	Quarry C. Alpena limestone series.	Top strata 2 ft. thick. (Below top shell).	Hand specimen......	Same as above.......
56		2nd strata, 2 ft. thick.	Hand specimen......	Same as above.......
57		3rd strata, 4 ft. thick.	Hand specimen......	Same as above.......
58		4th strata, 2 ft. thick.	Hand specimen......	Same as above.......
59		1st strata, 2 ft. thick.	Hand specimen......	Same as above.......
60	Quarry F. Alpena limestone series.	2nd strata, 1 ft. thick.	Hand specimen......	Same as above.......
61		3rd strata, 2 ft. thick.	Hand specimen......	Same as above.......
62		4th strata, floor of quarry.	Hand specimen......	Same as above.......
63	Richard Collins quarry N. E. of Alpena.	Alpena limestone series. Fragmental semi-porous limestone consisting of ground up organic remains.	Hand specimen......	*F. M. Brady, Illinois Steel Co.
64	Richard Collins quarry, sec. 12, T. 31 N., R. 8 E.	Quarry beds, fossiliferous limestone without distinct bedding.	Composite of hand specimens.	R. C. Banks, Lab. Univ. of Mich.
65	Same as above.	Limestone dipping away from coral reef. Upper layer rather blue and shaly.		*A. N. clark.........
66	Owen Fox quarry, across road from Collins quarry, Alpena.	Alpena limestone series. Unweathered and unfilled Acervularia, very porous.	Hand specimen......	*F. M. Brady, Illinois Steel Co.
67	Same as above.	Lower quarry beds. Compact light crystalline limestone.	Hand specimen......	Same as above.......
68	Same as above.	Upper quarry beds. Dark crystalline limestone.	Hand specimen......	Same as above.......
69	Same as above.	Fragment of unaltered Stromatopora.	Hand specimen......	Same as above.......
70	Near Lake Huron, north of Alpena.	Traverse limestones D-1		†A. N. Clark, Alma Sugar Co.
70b	Same as above.	Traverse limestones E		Same as above.......
71	Same as above.	Traverse limestones A		Same as above.......
72	Same as above.	Traverse limestones D-2		Same as above.......
73	Same as above.	Traverse limestones B		Same as above.......
74	Same as above.	Traverse limestones C		Same as above.......
75	Isaacson property, N. E. of Alpena Ptld. Cem. Co. quarry.	Two ft. below surface.		*S. H. Ludlow, Alpena Ptld. Cem. Co.
76	M. J. Griffin quarry, 1 mi. N. W. of Bolton, S. ½ sec. 5, T. 32 N., R. 7 E.	Quarry beds very crinoidal at top but shaly, bituminous, and crystalline near bottom.	Composite sample of hand specimens.	R. C. Banks, Lab. Univ. of Mich.

limestones by counties.—Con.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.		Remarks.
0.36	0.13		95.91	*53.75*	3.63	*1.74*	......	......	All samples show traces of sulphates and phosphates.
1.77	0.35		89.10	*49.93*	8.67	*4.15*	......	......	
0.33	0.18		98.37	*55.13*	0.92	*0.44*	......	......	
0.38	0.19		98.03	*54.94*	1.36	*0.65*	......	......	
1.38	1.21		96.35	*54.00*	0.94	*0.45*	......	......	
1.64	0.27		96.50	*54.08*	1.26	*0.60*	......	......	
1.46	0.54		96.92	*54.32*	0.98	*0.47*	......	......	
0.42	0.18		98.14	*55.00*	0.98	*0.47*	......	......	
0.68	0.26		98.03	*54.94*	1.05	*0.50*	......	......	
0.42	0.19	0.45	98.04	*54.94*	0.88	*.42*	S. 0.014	......	Samples collected by A. W. Grabau, 1901.
1.07	‡0.77		96.84	*54.27*	1.09	*0.52*	......	......	Samples collected by R. A. Smith.
	Insoluble 1.10		95.40	*53.46*	1.76	*0.84*	......	......	Samples collected by A. C. Lane.
0.24	0.16	0.26	98.88	*55.42*	0.45	*0.21*	S. 0.006	......	
0.32	0.29	0.33	94.83	*53.15*	4.20	*2.01*	0.020	......	
1.18	0.31	1.79	95.29	*53.40*	1.33	*0.64*	0.089	......	
0.24	0.16	0.32	98.84	*55.39*	0.43	*0.20*	0.007	......	
2.80	0.40		96.13	*53.87*	0.68	*0.32*	Undet.	......	SiO_2=insol. matter in HCl.
1.25	0.40		96.47	*54.06*	1.60	*0.76*	0.82	......	
8.60	1.40		88.86	*49.80*	0.38	*0.18*	0.76	......	
1.61	......	......	94.77	*53.11*	1.28	*0.61*	2.34	......	
1.75	......	......	97.70	*54.75*	0.60	*0.29*	......	......	
0.40	......	......	96.36	*54.00*	3.	*1.43*	0.24	......	
0.79	1.06		96.75	*54.22*	0.35	*0.17*	......	......	
1.11	‡1.21		95.02	*53.25*	2.27	*1.08*	......	......	Sample taken by R. A. Smith, Mich. Geol. Surv., 1914.

*A. W. Grabau, Stratigraphy of the Traverse Group, Ann. Rept. 1901, Mich. Geol. Surv., pp. 179-183.
†A. C. Lane, Ann. Rept. 1902, Mich. Geol. Surv., p. 173.
‡R_2O_3=Alumina, iron, etc.

Analyses of Michigan

ALPENA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
77	Same as No. 76.	Railroad cut, at surface.	Lime as burned......	*E. J. Schneider......
78	Same as above.			*E. J. Schneider......
79	Same as above.	1st quarry on suface of subterranean passage.	Lime as burned......	*E. J. Schneider......
80	Same as above.			*E. J. Schneider......
81	Same as above.	1st quarry, top layer 5 ft. from surface.	Lime as burned......	*E. J. Schneider......
82	Same as above.			*E. J. Schneider......
83	Same as above.	1st quarry, top layer 8 ft. from surface.	Lime as burned......	*E. J. Schneider......
84	Same as above.			*E. J. Schneider......
85	Same as above.	New quarry, top layer from surface.	Lime as burned......	*E. J. Schneider......
86	Same as above.			*E. J. Schneider......
87	Same as above.	Top layer ½ mile from new (?) quarry.	Lime as burned......	*E. J. Schneider......
88	Same as above.			*E. J. Schneider......
89	2 mi. N. of Alpena, S. W. cor. sec. 5, T. 31 N., R. 8 E.	Rock outcrops on road side. Highly fossiliferous (crinoid stems and brachiopods) limestone.	Hand specimens, from surface.	*F. M. Brady, Illinios Steel Co.
90	3½ mi. N. of Alpena, S. E. ¼ sec. 27, T. 31 N., R. 8 E.	Compact gray limestone overlying Stropheodonta shales. Long Lake beds.	Hand specimen......	Same as above.......
91	Alpena (exact location not given).	Specimen from Alpena limestone.	Hand specimen......	*W. M. Curtis.......
92	R. Collins quarry, N. E. of Alpena.	Quarry beds.........		*S. H. Ludlow, Alpena Ptld. Cem. Co.
93 to 138	(See text).			

ARENAC

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
140	Omsted quarry, S E. ¼ sec. 17, T. 19 N., R. 6 E.	Gray dolomite, 4 to 5 feet thick.		†W. M. Gregory.....
141	Jas. McDonnell (formerly Thos. Burt) quarry, 3 mi. NE of Omer. SE¼ SE¼ sec. 1, T. 19 N., R. 5 E.	Quarry beds. White crystalline to dense grained limestone, stained with iron and organic matter. 3 ft. thick.	Composite of several hand specimens.	R. C. Banks, Lab. Univ. of Mich.
142	Same as above.	Top stratum.........		†Dow Chem. Co......

*A. W. Grabau, Stratigraphy of the Traverse group, Ann. Rept. 1901, Mich. Geol. Surv., pp. 179-183.

†Lane, Limestone; Ann. Rept. 1903, Mich. Geol. Surv., p. 173.

limestones by counties.—Con.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.		Remarks.
1.81	1.54		......	93.44	......	2.99	......	......	
1.2	0.9		94.4	*52.90*	3.5	*1.6*	......	......	Calculated as limestone.
0.16	1.32		......	95.89	......	0.53	......	......	
0.2	0.8		95.5	*53.52*	0.6	*0.2*	......	......	Calculated as limestone.
1.67	1.42		......	96.96	......	0.49	......	......	
1.0	0.8		97.6	*54.70*	0.6	*0.2*	......	......	Calculated as limestone.
1.39	2.56		......	94.48	......	0.14	......	......	
0.8	1.5		97.5	*54.64*	0.2	*0.09*	......	......	Calculated as limestone.
2.85	1.10		......	93.51	......	1.69	......	......	
1.54	0.63		95.7	*53.63*	2.13	*1.02*	......	......	Calculated as limestone.
1.39	1.49		......	95.53	......	1.81	......	......	
1.8	0.9		97.9	*54.87*	3.20	*1.53*	......	......	Calculated as limestone.
4.62	0.45	1.15	92.38	*51.77*	1.36	*0.65*	Sul. 0.029	......	Samples by A. W. Grabau.
4.54	0.50	1.36	91.82	*51.46*	1.67	*0.80*	0.084	......	
1.318	0.536	1.159	95.231	*53.37*	0.946	*0.45*	Sul. traces.	......	Water, 0.3%; organic matter, 1.51%; chlorine, slight traces; alkalies, traces.
0.62	0.33	0.60	97.39	*54.58*	1.09	*.52*	......	......	

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
3.94	0.38	0.76	53.50	......	41.33	......	......	
4.78	‡1.52		92.53	51.86	1.00	.478	......	Samples by R. A. Smith, Mich. Geol. Surv., 1914.
1.92	0.23	0.25	95.00	53.24	1.94	.928	......	

‡R_2O_3=iron, alumina, etc.
NOTE: Numbers in italics calculated from original analyses.

Analyses of Michigan

ARENAC

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
143	M. J. Griffin quarry near W¼ post sec. 1, T. 19 N., R. 5 E., ¾ mi. NW of McDonnell quarry.	Gray to buff limestone. Much chert in nodules and irregular masses.	Hand specimen from clearest stone.	Dow Chem. Co.......
144	Apparently from SE¼ sec. 34 and SW¼ sec. 35, T. 20 N., R. 5 E.	Light gray to white fossiliferous limestone. Small exposure. Thickness unknown.		W. M. Gregory......
145	Harmon & Crowell quarry, SE¼ sec. 13 or NE¼ sec. 24, T. 20 N., R. 7 E.	Top stratum, 1½ ft. thick.	Hand specimen......	Crane & Co., Chicago Ill.

CHARLEVOIX

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
146	Charlevoix Rock Products Co., main quarry, SE¼ SE¼ sec. 28, T. 34 N., R. 8 W.	Quarry beds Nos. 1-3. Bed No. 1 light buff friable "sandy" looking limestone. Bed. No. 2 earthy, and No. 3 banded buff to dark gray. Section 20 ft.	Composite of hand specimens.	R. C. Banks, Lab. Univ. of Mich.
147	Charlevoix quarries, probably secs 28 & 29, T. 34 N., R. 8 W.	Traverse limestone...		Omega Ptld. Cem. Co., Jonesville.
148	Same as above.	Traverse limestone...		
149	Charlevoix Rock Products Co. quarry No. 2, SW¼ SE¼ sec. 28, T. 34 N., R. 8 W.	Top bed or No. 1. Yellow, friable earthy and very fossiliferous limestone, 3 ft. thick.	Hand specimen......	R. C. Banks, Lab. Univ. of Mich., 1915
150	Same as above.	Bed No. 3. Hard, gray, crystalline limestone, 4 ft. thick.	Composite of hand specimens.	Same as above.......
151	Wolverine Lime Co., Charlevoix. Quarry in S½ SE¼ sec 29, T. 34 N., R. 8 W.	Small quarry 7 ft. deep, gray crystalline limestone similar to bed 3 in quarry No. 2 of Charlevoix Rock Products Co.		Same as above.......

limestones by counties.—Con.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
0.90	0.24	0.44	96.60	54.14	1.78	.851	......	
5.90	0.12	0.36	92.30	51.72	1.32	.631	......	
3.24	1.74		93.57	52.45	1.68	.803	......	

‡R_2O_3=iron, alumina, etc.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium Carbonate. $MgCO_3$.	Magnesium Oxide. MgO.	Miscellaneous.		Remarks.
0.29	0.51		97.46	*54.62*	1.44	*0.69*	......	......	
0.18	0.22		98.76	*55.35*	0.71	*0.34*	SO_3 none	....	Analysis furnished by Andrew Dougherty.
0.66	0.44		97.47	*54.62*	1.32	*0.63*	SO_3 none	....	Same as above.
......	......	......	89.56	*50.19*	......	......	......	......	Stone much weathered.
1.21	1.40		95.94	*53.77*	1.24	....	phos. 0.026	....	
0.82	0.40	0.45	97.05	*54.39*	1.05	......	Sul. 0.039	Mn. 0.00	

NOTE: Numbers in italics calculated from original analyses.

Analyses of Michigan

CHARLEVOIX

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
152	Same as above.			
153	Wolverine Lime Co., Charlevoix, secs. 29 and 32, T. 34 N., R. 8 W.	Traverse limestones. Some or all of samples probably from quarry noted above.	Probably hand specimens.	D. H. Stacks, 1912.
154	Same as above.			
155	Charlevoix quarries, probably secs. 28 and 29, T. 34 N., R. 8 W.	Traverse limestones...	....	....
156	Same as above.	Traverse limestones...	....	R. E. Doolittle.......
157	Same as above.	Traverse limestones...	....	R. E. Doolittle, 1903..
158	Same as above.	Traverse limestones...	....	R. E. Doolittle, 1903..
159	Same as above.	Traverse limestones...	....	R. E. Doolittle, 1903..
160	Norwood, low bluff on lake shore 1 mi. N., NE¼ sec. 34, T. 33 N., R. 9 W.	Upper Traverse series. Gray drusy dolomite finely crystalline....	Hand specimen......	*Rominger..........
161	Norwood, old quarry 1½ mi. N-NE. near NW. cor. NE. ¼ sec. 26, T. 33 N., R. 9 W	Light gray lithographic to dense grained limestone with many small crystals of calcite. Thickness exposed 5 ft.	Composite of hand specimens.	R. C. Banks, Lab. Univ. of Mich., 1915
162	Northern Lime Co., Bayshore or "Standard" quarry, S½ S½ sec. 6, T. 34 N., R. 6 W.	W. end of quarry bed. White to light gray limestone at top; beds 3, 4, and 5; soft yellow "sugary" limestones. Section about 15 ft. Bed No. 2 worthless—not sampled.	Same as above.......	Same as above.......
163	Bayshore Lime Co., Bayshore quarry. (Now Northern Lime Co., "Standard" plant).	High calcium beds, lower part of quarry.	....	W. G. Banks, 1902...
164	Northern Lime Co., Bayshore or "Standard" quarry.	Lime as burned from quarry.	Lump lime..........	Ashland Steel & Iron Co., 1902.
165	Same as above.	Same as above.......	Lump lime..........	Elk Rapids Portland Cement Co.
(166-	173, see text).			
174	Bayshore, 1 mi. E on lake shore. (3 mi. E Khagashewing Point.—Rominger.	Dark lithographic limestones at and just above lake level. 2 beds, upper 6-8 ft. thick.	Hand specimens......	*Rominger..........
175	Northern Lime Co. "Superior" plant 2 mi. W. of Bayshore, S½ sec. 2, T. 35 N., R. 7 W.	Quarry beds Nos. 1-5; E. end. Yellowish white to yellow earthy limestones, laminated bituminous bed at bottom. Section 25 ft.	Composite of hand specimens.	R. C. Banks, Lab. Univ. of Mich., 1915
176	Khagashewing Point, old quarry.	Apparently the brownish sugary dolomites just below the light yellowish white earthy limestone seen in the Superior quarry of No. Lime Co.	Hand specimen......	*Rominger..........

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.		Remarks.
							S.	Mn.	
0.64	0.80	0.77	96.85	*54.28*	0.74	......	0.050	0.00	Analyses furnished by É. S. Stacks, Wolverine Lime Co.
0.58	0.60	0.63	96.72	*54.20*	0.88	......	0.073	0.00	
1.52	0.55	0.72	96.54	*54.10*	0.82	......	.038	0.00	
5.20	2.60		88.97	*49.86*	2.59	*1.23*	0.00	......	Analysis furnished by Andrew Dougherty.
5.20	3.12		90.93	50.92	0.87	*.42*	......	......	Same as above.
5.04	3.14		88.64	49.64	2.06	*.98*	......	......	Same as above.
5.10	2.48		91.42	51.20	0.92	*.44*	......	......	Same as above.
5.58	2.68		90.75	50.82	1.56	*.75*	......	......	Same as above.
Insol. 0.4	2.80		56.00	*31.38*	39.00	*18.66*	......	......	
1.28	0.75		96.70	*54.19*	1.19	*.57*	......	......	Sample by R. A. Smith, Mich. Geol. Surv.
0.16	0.55		79.16	*44.36*	20.03	*9.58*	......	......	
3.37	2.57		*91.77*	51.43	*1.04*	0.50	SO_3 0.60	......	Diff. 0.38 per cent.
Insol. 0.77	0.77		......	78.86	......	15.54	CO_2 + H_2O 4.06	......	
	1.12		......	73.45	......	19.09	6.60	......	
Insol. 1.00	......	......	98.00	*54.92*	1.00	*0.48*	......	......	Approximate average analysis.
0.44	0.36		89.39	*50.10*	9.80	*4.69*	......	......	Samples by R. A. Smith, Mich. Geol. Surv.
Insol. 0.50	1.50		58.00	*32.50*	38.00	*18.18*	......	......	

*Vol. III, Pt. I, pp. 58-60, Mich. Geol. Surv., 1869-1873.
Note: Numbers in italics calculated from original analyses.

Analyses of Michigan

CHEBOYGAN

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
177	Campbell Stone Co., Afton quarry. Sec. 36, T. 35 N., R. 2 W.	Top bed, light gray dense grained to crystalline limestone, 0-5 ft. thick. (cup corals).	Hand specimen......	R. C. Banks, Lab. Univ. of Mich., 1915
178	Same as above.	Bed No. 2 from top. Black bituminous coralline (cup corals) limestone, 6 ft. thick.	Hand specimen......	Same as above.......
179	Same as above.	Bed No. 3. "Paper stone" bed. Light gray crystalline limestone, 4 ft. thick....	Composite of hand specimen.	Same as above.......
180	Same as above.	Beds Nos. 5 & 6. Both beds very bituminous and laminated. No. 5, 2½ ft. thick; No. 6, 5½ ft. thick.	Same as above.......	Same as above.......
181	Same as above.	Beds 8, 9 and 10—lower 12 ft. of quarry	Same as above.......	Same as above.......
182	Same as above.	Light colored stone...	Hand specimen......	C. R. Lindfors, Mich. Sugar Co., 1907.
183	Same as above.	Black bituminous limestone, (Bed No. 2?).	Hand specimen......	Same as above.......
184	Campbell Stone Co., Afton. NW¼ NE. ¼ sec. 36, T. 35 N., R. 2 W	Drill core 4 to 42 ft. Present quarry section. 4 ft. of surface.	Drill core, average analyses (made every 2 ft.).	Campbell Stone Co. 1907.
185	Same as above.	Drill core 42 to 100 ft.	Same as above.......	Same as above.......
186	Campbell Stone Co., Afton. SW¼ SE¼ sec. 19, T. 35 N., R. 1 W.	Drill core 2 to 30 ft., 6 in.	Same as above.......	Same as above.......
186a	Black Lake quarry, 6 mi. N. of Onaway sec. 12, T. 35 N., R. 1 E.	Light gray fine grained limestone with calcite crystals.	Hand specimens......	R. C. Banks, Lab Univ. of Mich., 1915
187	Marion Stone Co., Afton, NE¼ sec. 7, T. 34 N., R. 1 W.	Quarry beds 1 to 5, and No. 7. Gray dense grained to crystalline limestone, fossiliferous in places. Section 21 ft.	Composite of hand specimens.	Same as above.......
188	W. G. Durrell property. Private claim 334.	Dundee limestone. Buff to gray bituminous limestone.	Hand specimens......	Prof. Stebbins.......
189	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
190	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
191	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
192	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
193	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
194	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
195	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
196	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
197	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
198	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
199	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
200	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
201	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
202	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
203	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
204	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
205	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
206	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......
207	Same as above.	Same as above.......	Hand specimens......	Prof. Stebbins.......

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
0.54	0.45		97.32	*54.54*	1.08	*0.52*	......	Samples by R. A. Smith, Mich. Geol. Surv.
0.63	0.62		92.60	*51.90*	2.56	*1.22*	Org. 2.61	Same as above.
0.24	1.44		96.97	*54.34*	0.12	*0.06*	......	Same as above.
0.28	0.37		98.04	*54.94*	1.07	*0.51*	......	Same as above.
1.75	0.64		95.75	*53.66*	1.24	*0.59*	......	Same as above.
1.00	0.14		97.68	*54.74*	1.05	*0.50*	Org. 0.05	Insol. SiO_2, 0.96%; sol. SiO_2, 0.04%; moisture 0.05%.
1.09	0.24		97.33	*54.54*	1.11	*0.53*	0.19	Insol. SiO_2, 1.06%; sol. SiO_2, 0.03%; moisture 0.04%.
2.10	0.34		96.52	*54.09*	0.90	*.43*	0.08	$CaCO_3$ varied from 95% to 97.40%. Analyses every 2 ft.
3. to 5.00	......	......	......	......	6. to 9.00	2.87 to 4.30	......	
3.40	0.38		94.20	*52.79*	1.80	*.86*	......	Similar analyses for cores from SW¼ NE¼ sec. 25, T. 35 N., R. 2 W., also from NW¼ SW¼ sec. 13, T. 34 N., R. 2 W., and NW¼ SW¼ of same section.
0.39	0.52		96.84	*54.27*	2.03	*.97*	......	Samples by R. A. Smith, Mich. Geol. Surv., 1914.
0.80	0.55		96.88	*54.29*	1.24	*.59*	......	Same as above.
......	Undet.		94.63	53.03	2.90	*1.39*	......	
......	Undet.		69.40	38.89	27.91	*13.35*	......	
......	Undet.		96.24	53.93	2.60	*1.24*	......	
......	Undet.		92.16	51.65	7.00	*3.35*	......	
......	Undet.		97.49	54.63	0.20	*.09*	......	
......	Undet.		97.69	54.74	0.72	*.34*	......	
......	Undet.		80.05	44.86	19.48	*9.32*	......	Analyses of samples from exposures on Mill Creek, numbered in order from mouth of creek up stream for about 1200 ft.
......	Undet.		98.83	55.38	0.87	*.42*	......	
......	Undet.		94.59	*53.01*	3.30	*1.58*	......	
......	Undet.		96.04	*53.82*	0.68	*.32*	......	
......	Undet.		97.10	*54.42*	0.80	*.38*	......	
......	Undet.		96.96	*54.34*	1.28	*.61*	......	
......	Undet.		96.18	*53.90*	1.75	*.84*	......	
......	Undet.		92.19	*51.66*	0.24	*.11*	......	
......	Undet.		94.94	*53.21*	0.80	*.38*	......	
......	Undet.		93.44	*52.37*	1.21	*.58*	......	
......	Undet.		94.91	*53.19*	3.66	*1.75*	......	
......	Undet.		94.08	*52.72*	1.50	*.72*	......	
......	Undet.		97.70	*54.75*	1.45	*.69*	......	
......	Undet.		96.25	*53.94*	1.65	*.79*	......	

Note: Numbers in italics calculated from original analyses.

Analyses[1] *of Michigan*
CHEBOYGAN

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
208	Same as 207	Same as No. 207	Hand specimens	Prof. Stebbins
209	Same as above	Same as above	Hand specimens	Prof. Stebbins
209a	Same as above	Same as above	Hand specimens	Prof. Stebbins
210	Same as above	Same as above	Hand specimens	Prof. Stebbins
211	Same as above	Same as above	Hand specimens	Prof. Stebbins
211a	Same as above	Same as above	Hand specimens	Prof. Stebbins
211b	Same as above	Same as above	Hand specimens	Prof. Stebbins
211c	Same as above	Same as above	Hand specimens	Prof. Stebbins
211d	Same as above	Same as above	Hand specimens	Prof. Stebbins
211e	Same as above	Same as above	Hand specimens	Prof. Stebbins
211f	Same as above	Same as above	Hand specimens	Prof. Stebbins
211g	Same as above	Same as above	Hand specimens	Prof. Stebbins
211h	Same as above	Same as above	Hand specimens	Prof. Stebbins
211i	Same as above	Same as above	Hand specimens	W. N. Thayer, Emery Inst. Cincinnati, O.
211j	Same as above	Same as above	Hand specimens	Same as above
211k	Same as above	Same as above	Hand specimens	Same as above
211l	Same as above	Same as above	Hand specimens	Same as above
211m	Same as above	Same as above	Hand specimens	Same as above
211n	Same as above	Same as above	Hand specimens	Same as above
211o	Same as above	Same as above	Hand specimens	Same as above
211p	Same as above	Same as above	Hand specimens	Same as above
211q	Same as above	Same as above	Hand specimens	Same as above
211r	Same as above	Same as above	Hand specimens	Same as above
211s	Same as above	Same as above	Hand specimens	Same as above
211t	Same as above	Same as above	Hand specimens	Same as above
211u	Same as above	Same as above	Hand specimens	Same as above
211v	Same as above	Same as above	Hand specimens	Same as above
211w	Same as above	Same as above	Hand specimens	Same as above
211x	Same as above	Same as above	Hand specimens	Same as above
211y	Same as above	Same as above	Hand specimens	Same as above
211z	Same as above	Same as above	Hand specimens	Same as above
211aa	Same as above	Same as above	Hand specimens	Same as above
212	W. G. Durrell quarry near mouth of Mill Cr. Private claim No. 334.	Sample taken at 18 in. from top of quarry.	Hand specimens	Lab. Kelley Island Lime & Transportation Co., Cleveland, Ohio.
213	Same as above	At 3 ft	Hand specimens	Same as above
214	Same as above	At. 7 ft	Hand specimens	Same as above
215	Same as above	At 10 ft	Hand specimens	Same as above
216	Same as above	Buff to gray and very dark bituminous limestone. Face 26 ft. 6 in. At 12 ft.	Hand specimens	Same as above
217	Same as above	At 16 ft	Hand specimens	Same as above
218	Same as above	At 18 ft	Hand specimens	Same as above
219	Same as above	At 20 ft	Hand specimens	Same as above
220	Same as above	At 22 ft	Hand specimens	Same as above
221	Same as above	At 26 ft	Hand specimens	Same as above
222	Same as above	At 26 ft	Hand specimens	Same as above
223	Same as above	Average	Hand specimens	Same as above
224	Same as above	Average 3-26 ft		
226	Same as above	Grayish buff crystalline bituminous limestone, E. bank of Mill Creek 250 ft. from highway; 22 ft. section.	Composite of samples taken 6 in. apart from 22 ft. ledge.	R. C. Banks, Lab. Univ. of Mich.
227	Same as above.	Same as above	Same as above	G. F. Harris, Mich. Limestone & Chemical Co., Rogers.
228	Same as above.	Basal magnesian beds of the Dundee. Soft light to dark buff "sugary" limestone, bituminous. Test hole 6 ft. deep.	Composite of several hand specimens.	A. R. Todd and W. B. Scovill, Dept. State Dairy and Food.

[1]Note: Numbers in italics are calculated from original analyses.

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $CaCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
......	Undet.		97.44	54.61	0.39	.18	......	
......	Undet.		97.14	54.44	0.90	.43	......	
......	Undet.		97.64	54.72	0.96	.46	......	
......	Undet.		97.63	54.71	0.17	.08	......	
......	Undet.		98.21	55.04	0.36	.17	......	
......	Undet.		98.43	55.16	0.99	.47	......	
......	Undet.		97.63	54.71	0.26	.12	......	
......	Undet.		96.05	53.83	0.12	.05	......	
......	Undet.		99.07	55.52	0.13	.06	......	
......	Undet.		97.09	54.41	0.90	.43	......	
......	Undet.		96.43	54.04	2.70	1.29	......	
......	Undet.		98.11	54.08	2.40	1.15	......	
......	Undet.		99.79	55.92	trace	......	......	
......	‡0.87		99.13	55.55	none	......	......	
......	1.47		98.53	55.22	trace	......	......	
......	0.78		99.22	55.60	none	......	......	Same as No. 207.
......	1.45		98.55	55.23	trace	......	......	
......	1.36		98.64	55.28	trace	......	......	
......	0.25		99.75	55.90	none	......	......	
......	1.47		98.53	55.22	trace	......	......	
......	1.54		98.46	55.18	trace	......	......	
......	0.41		99.59	55.81	none	......	......	
......	2.16		97.84	54.83	trace	......	......	
......	0.79		99.21	55.60	none	......	......	
......	1.44		98.56	55.23	trace	......	......	
......	1.23		98.17	55.02	trace	......	......	
......	1.88		98.12	54.99	trace	......	......	
......	0.88		99.12	55.55	none	......	......	
......	1.71		98.29	55.08	trace	......	......	
......	1.13		98.87	55.41	none	......	......	
......	2.08		97.92	54.88	trace	......	......	
......	1.82		98.18	55.02	trace	......	......	
0.16	Undet.		82.62	46.30	16.97	8.11	......	
0.24	Undet.		98.83	55.38	0.69	.33	......	
0.16	Undet.		98.28	55.08	1.36	.65	......	
0.12	Undet.		98.83	55.38	1.01	.48	......	
0.08	Undet.		97.84	54.83	1.92	.92	......	Samples collected by F. A. Jones, Mgr. Operations, Kelley Island Lime & Trans. Co., 1915.
0.44	Undet.		93.43	52.36	5.98	2.86	......	
0.16	Undet.		98.77	55.36	1.03	.49	......	
0.20	Undet.		98.60	55.25	1.08	.52	......	
0.20	Undet.		98.55	55.23	1.17	.56	......	
0.32	Undet.		98.83	55.38	1.27	.61	......	
0.12	Undet.		98.33	55.10	1.27	.61	......	
0.20	Undet.		96.62	54.14	3.02	1.44	......	
0.204	Undet.		98.028	54.93	1.678	.80	......	
1.67	*0.73		95.29	53.34	2.11	1.00	......	Samples collected by Mich. Geol. Survey.
1.10	0.20		96.52	54.05	2.00	0.96	......	Same as above.
1.97	*0.90		75.80	42.48	†21.33	10.20	......	Samples taken in 1915 by L. W. Durrell and C. B. Fleming.

*R_2O_3=iron, alumina, etc.
†Magnesium carbonate by difference, not weighed.
‡Includes silica, iron, and alumina.

Analyses[1] *of Michigan*

CHIPPEWA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
229	West Neebish Rapids, St. Marys River.	Hard crystalline dolomite with some sand.	Probably hand specimens.	....
230	NE. cor. of Encampment d'Ours Island.	Light colored brittle fossiliferous limestone; top beds.	Composite of 2 hand specimens.	*C. Rominger.
231	NE. cor. St. Joseph Island	Blue thin bedded nodular limestones with shale partings; middle strata.	Same as above.......	*C. Rominger........
232	Same as above.	Bluish or greenish very sandy limestone with shale streaks. Lowest exposed beds at water's edge.	Same as above.......	*C. Rominger........
233	Sulphur Island.	Sandy dolomite, top stratum on island.	Same as above.......	*C. Rominger........
234	Marblehead quarry, Drummond Island, sec. 31, T. 42 N., R. 7 E.	6 ft. bed at top of quarry. 36 ft. above Lake Huron. Dark gray very crystalline dolomite.	Rock specimen.......	*C. Rominger........
235	Same as above.	9 ft. bed below the 6 ft. bed. Yellowish white earthy fracturing dolomite.	Rock specimen.......	*C. Rominger........
236	Same as above.	Lower beds of quarry; crystalline dolomite.	Rock specimen.......	*C. Rominger........
236a	Drummond Island, exact location not given.	Niagara dolomite, siliceous and argillaceous.	....	W. G. Miller, Geol. Surv. Can.
237	Marblehead, Drummond Island. Outcrop short distance N. of quarry.	Ash colored acervularia limestone 3 ft. thick near lake level.	Rock specimen.......	*C. Rominger........
238	Same as above.	5 ft. drak gray bituminous nodular limestone, 30 ft. below acervularia bed.	Rock specimen.......	*C. Rominger........
238a	Same as above.	Lowest beds in the Marblehead section.	Rock specimen.......	*C. Rominger........
239	W. side Sitgreaves bay, Drummond Island.	Loose slabs just above the Hudson River group.	Rock specimen.......	*C. Rominger........
240	Ludlow Seaman quarry, Drummond Island.	Upper 19 ft. of quarry. Hard finely crystalline dolomite.	4 pieces, 1 from each bed.	L. C. Nodell and C. K. Wirth, Univ. of Mich., 1914.
240a	Quarry Pt., W. side Drummond Island.	Quarry stone, laminated beds.	Rock specimen.......	*C. Rominger........
240b	Same as above.	Sole bed of above quarry, more crystalline than the laminated beds.	Rock specimen.......	*C. Rominger........
241	Lime Island, old quarry just north of Pittsburg Coal Co., St. Mary's River.	Hard buff to white finely crystalline dolomite beds, 10 to 28 ft. above river level.	Composite sample, 4 rock specimens.	L. C. Nodell and C. K. Wirth, Univ. of Mich., 1914.

[1]Figures in italics calculated from original analyses.
*Vol. I, Pt. III, pp. 48 and 78.

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
†6.00	2.00		52.00	*29.14*	40.00	*19.13*	......	Residue of quartz sand.
†8.00	1.00		89.00	*49.87*	2.00	*.95*	......	Insoluble residue, quartzose.
†13.00	1.50		82.00	*45.95*	3.00	*1.43*	......	Insoluble residue, argillaceous.
†4.06	1.60		47.30	*26.51*	2.50	*1.19*	......	Residue chiefly of coarse quartz sand.
†12.00	3.00		47.00	*26.34*	38.00	*18.18*	......	Residue of quartz sand.
†3.00	2.00		62.00	*34.75*	33.00	*15.78*	......	Cloudy bituminous residue with some quartz granules.
†2.00	‡4.00		54.00	*30.26*	39.00	*18.65*	......	Bituminous and siliceous residue.
†7.00	2.00		58.00	*32.50*	32.00	*15.31*	......	Residue silicio-argillaceous.
4.33	4.14		51.18	*28.68*	39.38	*18.84*	......	Iron and alumina exceptionally high, probably from lower Lockport.
†2.00	2.00		95.00	*53.24*	1.00	*.48*	......	
†2.00	1.00		94.00	*52.68*	2.00	*.96*	......	Residue bituminous with some quartz granules.
†9.00	2.00		52.00	*29.14*	35.00	*16.74*	......	Silicio-argillaceous residue.
†6.00	3.00		52.00	*29.14*	38.00	*18.18*	......	Siliceous residue.
1.71	**0.67		*55.47*	31.09	*45.78*	21.90	......	Block stone quarried for construction purposes.
†1.00	1.00		60.00	*33.62*	32.00	*15.30*	......	Same as above.
†1.00	1.00		59.00	*33.06*	38.00	*18.17*	......	Siliceous residue.
1.25	**0.76		*56.40*	31.61	*44.55*	21.31	......	Stone formerly burned for lime.

**R_2O_3=alumina, iron, etc.
†Insoluble in HCl.
‡Chiefly alumina.

Analyses of Michigan

CHIPPEWA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
242	Point Detour, St. Marys River.	Engadine dolomite. Light gray crystalline dolomite.	Rock specimen.......	*C. Rominger........
243	Outcrop on logging railroad, sec. 8, T. 42 N., R. 2 E.	Engadine dolomite. Blue coarsely crystalline dolomite.	Rock specimen.......	L. C. Nodell and C. K. Wirth, Univ. of Mich., 1914.
244	¾ mi. S. of Haff P. O. (Dick) sec. 29, T. 44 N., R. 5 W., on Trout Lake-Ozark road.	Engadine dolomite, lower 20 ft. bed. Bluish coarsely crystalline dolomite, 2 ft. from top of bed.	Rock specimen.......	Same as above.......
245	Same as above.	Engadine dolomite, upper 30 ft. bed. Bluish gray coarsely crystalline dolomite, 20 ft. from bottom of bed.	Rock specimen.......	Same as above.......
246	Haff P. O. (Dick), sec. 20, T. 44 N., R. 5 W., N. side of high bluff. Property of L. O. Poquin.	Engadine (?) dolomite or fossiliferous beds beneath.	Several rock specimens.	Dr. A. H. White, Mich. Univ. Lab.

DELTA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
247	John Bichler quarry, Groos P. O., 4 mi. N. of Escanaba.	Bluish argillaceous limestone. Top 11 ft.	Composite of 3 hand specimens.	L. C. Nodell and C. K. Wirth, Lab. Univ. of Mich., 1914.
248	Same as above.	Bluish argillaceous and fossiliferous limestone. Lower beds in quarry.	Composite of 2 hand specimens.	Same as above.......
249	East bank Escanaba River 1 mi. above mouth.	Bluish argillaceous and siliceous dolomite, highest strata exposed along river.	....	*C. Rominger........
250	Escanaba River 1½ mi. above mouth.	Wedge-shaped siliceous limestones next below the top strata.	....	*C. Rominger........
250a	White Fish River.	Trenton limestone.	....	*C. Rominger.

*Vol. I, Pt. III, pp. 48 and 78.
†Insol. in HCl.

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
†1.00	traces.		56.00	*31.38*	43.00	*20.57*	......	
0.39	**0.22	......	56.24	31.52	43.06	22.60	......	Typical specimen.
0.47	**0.23	......	55.94	31.35	42.77	20.46	......	Bed very uniform in general character from top to bottom
0.32	**0.33	......	56.31	31.56	43.23	20.68	......	Same as above.
0.80	0.32	0.71	52.97	29.76	44.22	21.16	......	Sample dried at 105°-107°. Sample furnished by L. O. Poquin.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
4.73	**2.71		*73.80*	41.36	*17.70*	8.51	......	Sample collected by Mich. Geol. Surv.
4.85	**2.55		*79.92*	44.79	*13.25*	6.34	......	Same as above.
†5.50	3.00		52.00	*29.14*	38.50	*18.42*	......	Insoluble residue, silicio-argillaceous.
†6.40	1.00		88.00	*49.32*	4.00	*1.91*	......	Insoluble residue, siliceous.
7.00	2.50		51.00	......	38.00	......	......	Quartzoze residue.

‡Chiefly alumina.
**R_2O_3=alumina, iron, etc.
Note.—Numbers in italics are calculated from original analyses.

Analyses of Michigan

DELTA

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
251	Lower Falls of Escanaba River, 6 mi. above mouth.	Fossiliferous, shaly, and sandy limestones below the wedge-shaped limestones.	....	*C. Rominger........
252	Old quarry on N. bank of Days River, NE. sec. sec. 3, T. 40 N., R. 22 W.	Buff gray crystalline limestone. 6-ft. exposure.	2 hand specimens.....	L. C. Nodell and C. K. Wirth, Lab. Univ. of Mich., 1914.
253	Road cut 1 mi. NW. Rapid River NE. cor. sec. 19, T. 41 N., R. 21 W.	Buff gray crystalline and fossiliferous limestone. 4 ft. exposure.	Hand specimen......	Same as above.......
254	Burnt Bluff, sec. 24, T. 38 N., R. 19 W.	Thin bedded dolomites lower 60 ft. of bluff.	Hand specimen......	*C. Rominger........
255	to 281, see text.			

EATON

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
282	Burt Portland Cement Co. quarry, Bellevue.	Main quarry beds, white to light gray limestone 12 ft. thick, east side of quarry.	Hand specimen,.....	R. C. Banks, Lab. Univ. of Mich.
283	Same as above.	White limestone, main quarry beds.	....	C. H. Denman, Burt Ptld. Cem. Co.
284	Bellevue quarries.	Light colored limestone with smooth conchoidal fracture, 8-10 ft. thick.	....	†C. Rominger........
285	Burt Portland Cement Co. quarries, Bellevue.	White to light gray limestones. Anal. of matter sol. in HCl.	....	H. R. Brown........
286	Same as above.	White to light gray limestones. Anal. of gangne insol. in HCl.	....	....
287	Same as above.	Brown dolomite stratum near top of quarry beds; 1 foot thick.	....	†C. Rominger........
288	to 294, see text.			

*Vol. I, Pt. III, pp. 48 and 78, Mich. Geol. Surv.
†Vol. III, Pt. I, p. 113.

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
‡20.80	2.40		55.8	*31.27*	21.00	*10.00*	......	Insoluble residue of quartz sand and some clay.
6.81	†2.96		*82.49*	46.79	*4.24*	2.03	......	Samples collected by Mich. Geol. Surv.
5.14	†2.51		*81.98*	45.95	*10.36*	4.96	......	Same as above.
‡2.50	1.00		56.60	*31.72*	39.00	*18.65*	......	

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $CaCO_3$.	Magnesium oxide. MgO.	Remarks.
2.56	R_2O_3 1.59		94.78	53.12	1.03	0.492	
1.30	0.99	0.66	95.98	53.79	2.04	0.975	Analysis furnished by the Burt Ptld. Cement Co.
{ Insol. 1.50	{ Hyd. 0.50		96.00	53.80	1.00	0.478	
{ Sol. 0.1208	{ 0.2093 FeO 0.2916	0.1008	95.10	53.300	1.009	0.483	Manganese 0.0449; arsenic, trace; sulphuric anhydrite.
{ Insol. 1.984		0.369	37.47	0.21	......	......	Sulphur as pyrites 0.175; organic matter 0.1334; diff. 0.145.
{ Insol. 9.00	5.50		56.00	31.38	23.00	11.00	

†R_2O_3=iron, alumina, etc.
‡Insoluble in HCl.
NOTE:—Figures in italics calculated from original analysis.

Analyses of Michigan

EMMET

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
295	No. Lime Co., quarry C, (W. quarry) Petoskey. Formerly Mich. Lime Co. In bluffs along Little Traverse Bay	Top 15 feet..........	....	E. D. Campbell, Lab. Univ. of Mich., 1901
296	Same as above.	Next 10 feet.........	....	Same as above.......
297	Same as above.	Next 6 feet..........	....	Same as above.......
298	to 302, see text.			
303	No. Lime Co., Petoskey, quarry C.	Gray earthy limestone with streaks of lithographic stone. Lower 22 ft. of main quarry.	Composite of hand specimens.	R. C. Banks, Lab. Univ. of Mich., 1915
304	No. Lime Co., Petoskey, Test pit next the office in quarry C.	Gray lithographic to dense grained earthy limestone. Lower beds with bituminous laminae. Sect. about 8 ft.	....	Same as above.......
305	No. Lime Co., Petoskey, quarry B.	Beds Nos. 2, 3, 4, 7 and 8 from top.	....	Same as above.......
306	Same as above.	Bed No. 6, high calcium bed. Densely crystalline to earthy limestone. Burned for chemical lime; 6 ft. thick.	....	Same as above.......
307	Same as above.	Bed No. 1. Top coralline and stromatoporoid dolomitic limestone. Mass of fossils in matrix of buff friable "brown sugary" limestone; 15-20 ft. thick.	Hand specimens......	Same as above.......
308	Petoskey, quarry uncertain.	Dark fine grained bituminous limestone with shale like appearance. Strong odor of petroleum when struck.	Hand specimens......	A. N. Clark, Alma Sugar Co., 1902.
309	Same as above.	"Stratum 1"........	Keg of samples......	Same as above.......
310	Same as above.	"Stratum 2"........	Keg of samples......	Same as above.......
311	Antrim Lime Co., Petoskey. Western part of city.	Upper 12 ft. of quarry. White earthy limestone.	Composite of hand specimens.	R. C. Banks, Lab. Univ. of Mich., 1915
312	Same as above.	Lower 12 ft. of quarry; upper beds white and earthy; lower buff laminated earthy to druse grained.	Same as above.......	Same as above.......

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Miscellaneous.	Remarks.
0.29	0.04	1.79	56.51	*31.67*	42.65	*20.40*	....	
0.10	Aver. 0.01	0.83	71.42	*40.03*	27.89	*13.34*	....	Analyses furnished by No. Lime Co.
....		0.60	92.23	*51.69*	6.00	*2.87*	....	
0.68		0.27	82.50	*46.24*	16.30	*7.80*	....	Samples by R. A. Smith, Mich. Geol. Surv.
0.26		0.32	96.36	*54.00*	2.58	*1.23*	....	Same as above.
0.22		0.23	86.14	*47.28*	13.11	*6.27*	....	Same as above.
0.26		0.28	94.78	*53.12*	4.18	*2.00*	....	Same as above.
0.09		0.46	62.86	*35.23*	36.41	*17.42*	....	Same as above.
Insol. 0.44		0.43	96.58	*54.13*	2.00	*.96*	....	Bed uncertain but probably from bituminous laminated beds in test pit in quarry C, Northern Lime Co., Petoskey.
Insol. 1.03		0.80	83.05	*46.54*	15.11	*7.23*	....	
Insol. 1.21		0.70	90.62	*50.79*	7.47	*3.57*	....	
0.18		0.29	97.40	*54.59*	2.15	*1.03*	....	Samples by R. A. Smith, Mich. Geol. Surv., 1914.
0.87		0.58	87.14	*48.84*	11.33	*5.42*	....	Same as above.

NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan

EMMET

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
313	Petoskey Crushed Stone Co. Quarry 4 mi. W. of Petoskey, sec. 11, T. 34 N., R. 6 W.	Thick bedded hard tough crystalline beds at east end of quarry, used for road metal. Sect. about 35 ft., upper 12 ft. sampled.	Same as above.......	Same as above.......
314	W. E. Smith, et. al. property 4½ mi. W. of Petoskey. (Old quarry of Petoskey Stone & Lime Co.) NE¼ NE¼ sec. 9, T. 34 N., R. 6 W	Top bed of quarry. Bed badly broken. Sect. exposed 3 to 4 ft.	Same as above.......	Same as above.......
315	Same as above.	Quarry beds Nos. 2, 3, 5, 7, 8, 9, 10, and 11, Sect. about 20 ft.	Same as above.......	Same as above.......
316	Same as above.	Lowest exposed beds at foot of trestle and below quarry floor. Beds Nos. 12 and 13 white earthy limestone. Thickness exposed 4 ft.	Same as above.......	Same as above.......
317	W. E. Smith, et. al., property 4½ mi. W. of Petoskey. Test pit on E end near S¼ post, sec. 3, T 34 N., R. 6 W.	Test pit beds. Gray lithographic limestone with fossils and calcite crystals. Bottom bed fossiliferous and crystalline. Section 5 ft.	Same as above.......	Same as above.......

HURON

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
318	Wallace Stone Co., Bayport quarries, N E½ sec. 5, T. 16 N., R. 10 E.	2nd bed from top. Tough gray limestone 3 ft. thick. Formerly burned for hot lime.	....	*Prof. Langley.......
319	Same as above.	Beds 3 and 4. Tough gray sandy magnesian limestones, each 3 ft. thick.	....	*A. C. Benedict......

*Vol. VII, Pt. II., pp. 214 and 216, Mich. Geol. Surv., 1900.

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
1.00	0.81		93.00	*52.12*	44.96	*2.37*	Same as above.
0.75	0.63		83.90	*47.02*	14.38	*6.88*	Same as above.
0.71	0.41		93.96	*52.66*	4.65	*2.22*	Same as above.
2.50	1.74		80.88	*45.33*	14.84	*7.10*	Same as above.
1.77	1.20		94.68	*53.06*	2.02	*.96*	Same as above.

COUNTY.

Silca. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
3.330		1.334	91.538	51.29	0.944	.451	Stratum now quarried away.
20.85	FeS_2 0.15	2.04	61.52	34.48	14.50	6.93	Silica is free sand.

NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan

JACKSON

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
320	Old quarries N E of Parma, probably in sec. 29, T. 2 S., R. 2 W.	Brown cellulose dolomite, argillaceous and ferruginous; upper stratum.	....	*C. Rominger........
321	One mi. NE of Parma in road on N side sec. 30, T. 2 S., R. 2 W.	....	Hand sample........	Mich. Ptld. Cem. Co., Chelsea, 1915.
322	Same as above.	....	Hand sample........	Same as above.......
323	Secs. 11 and 12, T. 3 S., R. 2 W., on main road from Jackson to Spring Arbor	....	Hand sample........	Same as above.......
324	In road between secs. 24 and 25, T. 3 S., R. 2 W.	....	Hand sample........	Same as above.......
325	Old Shoemaker farm 3 mi. S of Jackson, possibly in secs. 15 or 16, T. 3 S., R. 1 W.	Light colored limestone bed below 4 or 5 ft. of brown ferruginous cellulose dolomite.	....	*C. Rominger........
326	3 mi. S. of Jackson in railroad cut, Cincinnati & Northern Ry.	Light gray fine grained limestone, 4 to 6 ft. deep.	Hand sample........	Same as above.......
327	Old quarry, Allen farm E½ SE¼ sec. 2, T. 2 S., R. 1 W.	Light gray fine grained limestone 4 to 5 ft. thick.	Crusher run sample..	Mich. Ptld. Cem. Co., Chelsea, 1915
328	Same as above.	Same as above.......	Crusher run sample..	Same as above.......
329	Old quarry, Allen farm, E½ SE¼ sec. 2, T. 2 S., R. 1 W.	Light gray fine grained limestone 4 to 6 ft. thick.	Hand sample........	Same as above.......
330	Same as above.	Same as above.......	....	....
331	Old quarry on Haar farm, SE¼ SW¼ sec. 1, T. 2 S., R. 1 W.	Light gray fine grained limestone 8 to 10 ft. thick.	Hand sample........	Mich. Ptld. Cem. Co., Chelsea, 1915.
332	Old quarry near center sec. 1, T. 2 S., R. 1 W.	Light gray fine grained limestone 4 to 6 ft.	Hand sample........	Same as above.......
333	Old quarries about 3 mi. N of Jackson on N. side of Portage river sec. 1, T. 1 S., R. 1 E., and SW¼ sec. 6, T. 1 S., R. 2 E.	Light colored "smooth," compact, "brittle" limestone, 0-9 ft. thick.	....	*C. Rominger........
334	to 394, see text.			

*Vol. III, Pt. I, pp. 115, 116, 117, Mich. Geol. Surv., 1873-1876.

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
Insol. 2.90		18.40	63.70	35.70	11.4	5.45	
2.74		1.26	*94.32*	52.86	......	trace	
14.08		2.56	*81.58*	45.72	......	not det	Analyses furnished by N. S. Potter, Jr., V. P. and Gen'l. Mgr. Mich. Ptld. Cem. Co., Chelsea, Mich.
9.04		0.80	*85.89*	48.14	*1.71*	0.82	
4.22		1.68	*29.80*	29.80	*43.38*	20.75	
4.00		1.00	94.00	34.63	1.00	.478	Silica is quartz sand.
6.72		5.26	*71.16*	39.88	*16.43*	7.86	
2.80		0.78	......	53.22	......	0.00	
1.28		0.56	......	54.70	......	......	
2.50		0.88	*96.96*	54.34	......	*0.00*	Analysis furnished by N. S. Potter, Jr., V. P. and Gen'l. Mgr., Mich. Ptld. Cem. Co., Chelsea, Mich.
2.30		0.94	*96.53*	54.10	......	*0.00*	
1.60		2.00	*90.75*	50.86	*.77*	0.37	
3.20		1.94	*93.21*	52.24	*1.90*	0.91	
Insol. 1.40		0.70	96.90	70.62	1.00	.478	

NOTE:—Figures in italics calculated from original analyses.

Analyses of Michigan

MACKINAW

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
395	Fiborn quarry, sec. 20 and 28 T. 44 N., R. 7 W.	Fiborn limestone 18 to 30 ft. thick. Massive buff gray lithographic limestone locally filled with disseminated calcite crystals.	3 rock specimens.....	Lab. Univ. of Mich., 1916.
396	Same as above.	Fiborn limestone, bottom magnesium stratum, 1-2 ft. thick.	Hand specimen......	Same as above:......
397	Same as above.	Same as above.......	Hand specimen......	Bachtenkircher,......
398	Same as above.	Fiborn limestone. Lithographic limestone with disseminated calcite crystals.	Lime burned from Fiborn limestone.	L. D. Frauenfelder...
399	Same as above.	Same as above........	....	Fiborn Limestone Co.
400	Hendricks quarry, Union Carbide Co., sec. 6, T. 44 N., R. 9 W.	Top white crystalline magnesian beds, 1-7 ft. thick. Beds 1 and 2.	Hand specimens......	L. C. Nordell & C. K. Wirth, Lab. Univ. of Mich., 1914.
401	Same as above.	Fiborn limestone. Bed No. 3, 18 ft. thick. Grayish buff lithographic limestone with disseminated calcite crystals.	Hand specimens......	Same as above.......
402	Same as above.	Fiborn limestone. Bed No. 3, 18 ft. thick. Bottom of bed.	Hand specimens......	Same as above.......
403	Same as above.	Test pit, Bed No. 4, upper part, 4 ft. thick. From floor of main quarry.	Hand specimens......	Same as above.......
404	Same as above.	Test pit, Bed No. 4, lower part, hard white crystalline limestone, 4 ft. thick	Hand specimens......	Same as above.......
405	Same as above.	Test pit, Bed No. 5, dark buff gray dense grained limestone, 1 ft. thick.	Hand specimens......	Same as above.......
406	Same as above.	Test pit, Bed No. 6, hard white thinly bedded crystalline limestone, 2 ft. thick	Hand specimens......	Same as above.......
407	Same as above.	Test pit, Bed No. 7, hard white crystalline dolomite 2½ ft. thick.	Hand specimens......	Same as above.......
408	Same as above.	Test pit, Bed No. 8, brownish and drusy dolomite 6 ft. thick.	Hand specimens......	Same as above.......
409	Same as above.	Test pit 20 ft. deep in floor of main quarry. Bed No. 9, earthy limestone 1 ft. thick just above floor of pit.	Hand specimens......	Same as above.......
410	to 422, see text.			
423	5 mi. N. of Engadine, cen. sec. 29, T. 44 N., R. 10 W., dug well of Aug. Wandland.	Fiborn limestone; gray to buff lithographic limestone with disseminated calcite crystals, 6 ft. thick.	2 rock specimens blasted from well.	Same as above.......

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
0.58	†0.46		94.95	53.19	*2.34*	1.12	Samples collected by R. A. Smith, Mich. Geol. Surv.
1.10	†0.35		*92.71*	51.46	*8.99*	4.30	Same as above.
1.60	†0.60		94.95	*53.21*	*5.22*	2.50	Commercial analysis.
1.10	†0.80		95.35	*53.43*	1.55	*0.74*	Commercial anaylsis.
1.13	0.37		*95.39*	53.46	*3.05*	1.46	
0.66	†0.57		*75.55*	42.34	*26.57*	12.71	Samples collected by R. A. Smith, Mich. Geol. Surv.
1.00	†0.34		*98.22*	55.05	*1.69*	0.81	Same as above.
0.73	†0.29		*89.65*	55.29	*1.71*	0.82	Same as above.
0.83	†0.46		*96.16*	53.89	*2.82*	1.35	Same as above.
0.55	†0.55		*90.89*	50.89	*8.69*	4.16	Same as above.
0.36	†0.36		*98.65*	55.29	*2.19*	1.05	Same as above.
0.49	†0.18		*91.69*	51.39	*8.76*	4.19	Same as above.
1.61	†0.82		*57.63*	32.30	*42.77*	20.46	Same as above.
2.51	†0.86		*56.87*	31.87	*42.12*	20.15	Same as above.
0.71	†0.16		*99.47*	55.75	*1.46*	0.70	Same as above.
2.84	†0.91		*85.15*	47.72	*12.39*	5.93	Samples collected by Mich. Geol. Surv., 1913.

†R_2O_3=iron, alumna, etc.
NOTE: Figures in italics calculated from orignal analyses.

Analyses of Michigan

MACKINAW

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
424	1½ mi. W of Gould City, Secs. 30 and 31, T. 43 N., R. 11 W.	Fiborn limestone, gray to buff lithographic limestone with disseminated calcite crystals; exposure 4 ft.	Rock specimen from crevice.	Same as above.......
425	Bluff 1 mi. N. Hunt Spur, sec. 6, T. 42 N., R. 12 W.	Fiborn limestone; gray lithographic limestone with disseminated calcite crystals; bluff 15-20 ft. high.	Rock specimen.......	Union Carbide Co....
426	Ozark, Ozark Limestone Co. quarry.	Engadine dolomite. Coarsely crystalline dolomite, mottled and streaked with blue and filled with drusy cavities.	Crushed quarry product.	Univ. of Mich. Lab., 1916.
427	Same as above.	Same as above.......	Same as above.......	Algomah Steel Co....
428	Kenneth, property of Mr. Ross.	Engadine dolomite...	....	Minnesota Testing Lab., Duluth, Minn.
429	1 mi. W. of Engadine on the railroad near the summit of the grade.	Engadine dolomite. Upper bed, massive bluish crystalline dolomite, 8 ft. + thick.	Rock specimen from near top of ledge.	L. C. Nodell & C. K. Wirth, Lab. Univ. of Mich., 1914.
430	1 mi. W. of Engadine under railroad culvert.	Engadine dolomite, lower bed. Massive crystalline dolomite, 7 + ft. thick.	Rock specimen from culvert.	Same as above.......
431	1 mi. W. of Engadine on railroad.	Engadine dolomite...	Rock specimens......	L. D. & D. E. Frauenfelder, Supt. Iron & Chem. Co.
432	Point Aux Chenes gypsum quarries.	Dolomite, earthy interbedded gypsum and siliceous and argillaceous matter.	....	*C. Rominger........
433	Bed of Carp River, ½ mi. from mouth.	Lowest dolomites of the Monroe-Salina group.	....	*C. Rominger........
434	St. Martins Island, Lake Huron.	Variegated marl from gypsum bearing portion of the Monroe-Salina group.	....	*C. Rominger........
435	Mackinac Island, "Blanchart's farm"	Fossiliferous dolomitic limestone, upper part of Monroe formation.	....	*C. Rominger........
436	East side of Mackinac Island, near water level.	Dolomite...........	....	*C. Rominger........

*Vol. I, Pt. III, p. 78, Mich. Geol. Surv.

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
0.77	†0.53		*96.89*	54.30	*3.41*	1.63	Same as above.
1.20	†0.24		96.82	53.70	*3.64*	1.74	Analyses furnished by Guy D. Welton, Hunt Spur, Mich.
0.26	0.11		*54.08*	30.28	*42.83*	20.49	Analysis furnished by F. W. Hough, owner of quarry.
0.56	1.65		53.70	*30.09*	42.68	*20.41*	Same as above.
0.40	0.77	0.23	54.73	*30.67*	43.89	*20.99*	
0.87	†0.32		56.35	31.58	44.85	21.44	Samples collected by Mich. Geol. Surv., 1913.
1.03	†0.28		*54.38*	30.48	*46.66*	22.32	Samples collected by Mich. Geol. Surv., 1913.
0.70	0.55		54.81	*30.71*	43.71	*20.91*	Average of 2 analyses furnished by G. J. Nicholson, White Marble Lime Co., Manistique.
‡30.00	10.00		46.00	28.78	14.00	6.69	Silicio-argillaceous matter, residue.
2.00	1.00		53.00	29.70	44.00	21.04	Residue of crystals of sulphate of baryta and bituminous substances.
30.00	7.00		41.00	22.97	22.00	10.50	Residue chiefly siliceous sand.
8.00	2.00		68.00	38.10	22.00	10.52	Residue silicio-argillaceous matter.
....	....		55.00	30.82	44.00	19.61	Residue of iron, alumina and bituminous matter.

†R_2O_3=iron, alumina, etc.
‡Insoluble in HCl.
NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan

MARQUETTE

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
437	Near junction of east and west branches of Escanaba river.	Sandy dolomite......	Hand specimens, probably.	*C. Rominger........
438	Same as above.	Brecciated dolomites, lowest exposed beds.	Same as above.......	*C. Rominger........
439	Bed of E. branch of Escanaba River above junc. with West branch.	Sandy dolomite with Lingula antique boulder from bed below the brecciated dolomites.	Same as above.......	*C. Rominger........
441	Sec. 16, T. 42 N., R. 24 W., on Escanaba River.	Light colored brittle limestone with conchoidal fracture, lower Trenton strata	....	*C. Rominger........
442	Foot of Grand Rapids, Menominee River, Menominee.	Fine grained thin bedded crystalline sandy dolomite with shale partings. Highest exposed beds.	....	*C. Rominger........
443	Middle of Grand Rapids, Menominee River.	Variegated dolomite banded or mottled with red. Bed 3 ft. thick.	....	*C. Rominger........
444	Head of Grand Rapids, Menominee River.	Hard dolomite and oolite beds. Thickness 4 ft.	....	*C. Rominger........

*Vol. I, Pt. III, p. 78, Mich. Geol. Surv.

MENOMINEE

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
445	Robt. Rick quarry, Menominee, NE ¼ sec. 14, T. 32 N., R. 26 W.	Buff gray argillaceous and crystalline with thin limestones of clayey matter; 4 ft. face.	Composite sample of two hand specimens.	L. C. Nodell & C. K. Wirth, Lab. Univ. of Mich., 1914.
446	Menominee, Menominee Co.	Bed uncertain but probably upper Trenton strata; "Menominee Marble."	....	N. H. Winchell.......

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
†15.00	0.80		47.00	*26.34*	37.00	*17.70*	Residue of quartz sand.
†15.00	2.50		49.00	*27.46*	32.00	*15.31*	Residue siliceous.
†14.00	2.00		50.00	*28.02*	33.00	*15.78*	Residue of quartz sand.
†4.60	1.00		90.00	*50.43*	3.00	*1.44*	Insoluble residue, siliceous.
†18.00	2.00		45.00	*25.22*	35.00	*16.74*	Insoluble residue, siliceous.
†23.00	1.00		42.00	*23.54*	53.60	*25.64*	Insoluble residue of siliceous sand with dark bituminous sediment.
†2.00	1.00		54.00	*30.26*	42.00	*20.09*	Insoluble residue, siliceous.

†Insoluble in HCl.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
3.59	‡2.72		*52.03*	29.16	*41.99*	20.09	Samples collected by Mich. Geol. Surv.
‡0.472	0.365		54.621	*30.61*	43.932	*20.01*	Analysis from N. H. Winchell's field notes, 1869-70.

‡R_2O_3=iron, alumina, etc.
NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan
MONROE

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
447	Shore Line Stone Co., quarry, Claim 64, 2 mi. N. of Monroe, formerly Monroe Stone Co.	Dark drab dolomite 2 ft. from top of quarry.	....	K. J. Sundstrum.....
448	Same as above.	Dark drab dolomite 7 ft. from top of quarry.	....	K. J. Sundstrum.....
449	Same as above.	Dark drab dolomite 10 ft. from top of quarry.	....	K. J. Sundstrum.....
450	The France Stone Co., Monroe.	Dark gray dolomites of the middle portion of the quarry face.	Average of 5 analyses.	*W. H. Sherzer......
451	Woolmith quarry, NE¼, SE¼ sec. 21, T. 5 S., R. 8 E.	Dolomite, top 4 ft. of quarry beds.	....	†Prof. McDermott....
452	Same as above.	Dark brown porous petroliferous dolomite with black blotches; 3 ft. thick and directly above the Sylvania sandstone.	....	†Prof. McDermott....
453	Grape quarries, N. bank of Raisin river, Claim 516, T. 6 S., R. 7 E., Monroe.	Buff gray compact dolomite with nodules and masses of chert. Thickness 12 ft.	....	J. D. Pennock of Solvay Process Co., Detroit.
454	Lulu quarry, NW¼ NW¼ sec. 16, T. 7 S., R. 7 E.	Compact gray dolomites more or less streaked and mottled with blue like castile soap. Thickness 8-9 ft. Lower part of quarry.	....	**C. Rominger.......
455	Same as above.	Dolomitic sandstone, lower 3 ft. of quarry beds.	....	**C. Rominger.......
456	Drill core NE¼ SW¼ sec. 8, T. 5 S., R. 9 E.	Dolomite..........	....	S. T. Crapo, Gen. Mgr. Pere Marquette R. R.
457	1½ mi. W. of Ida, cen. sec. 4, T. 7 S., R. 7 E.	Light gray "gashed" or acicular dolomite.	....	**C. Rominger.......
458	Christiancy quarry near mouth of Macon river, SW. cor sec. 5, T. 6 S., R. 6 E.	Bed A, fossiliferous gray limestone at top of quarry.	....	G. A. Kirschmeier...
459	Same as above.	Bed B, brownish limestone 4 to 4 ft. 6 in. thick.	....	G. A. Kirschmeier....
460	Same as above.	Bed C, soft dark gray limestone 7 to 8 ft. thick.	....	G. A. Kirschmeier....
461	Same as above.	Bed D, similar in appearance to C but higher in $CaCO_3$.	....	G. A. Kirschmeier....
462	Same as above.	Bed A, as above......	....	K. J. Sundstrum.....
463	Same as above.	Bed B, as above......	....	K. J. Sundstrum.....

*Pub. 2, Geol. Ser. 1, The Monroe Formation, Mich. Geol. and Biol. Surv., 1909, p. 37.
†W. H. Sherzer, Geol. Rept. on Monroe Co., Mich. Geol. Surv., Vol. VII, Pt. I, 1900, pp. 82, 83, 92, 95.

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3. / Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
2.00	0.70	54.54	30.56	42.75	20.45	
0.74	0.98	54.47	30.52	43.59	20.85	
1.33	0.58	54.94	30.79	42.84	20.49	
3.08	to 6.08	50.92 to 53.50	....	41.39 to 44.77	......	
6.19	0.45	50.12	28.08	43.53	20.82	
3.05	0.31	52.72	29.54	44.59	21.33	
3.45	0.20	51.69	28.96	45.01	21.53	
‡4.00	....	54.00	30.26	42.00	20.09	
‡54.00	....	46.00	25.78	......	......	The calcium carbonate is undoubtedly in part magnesium carbonate.
‡2.32	0.48	55.03	30.84	42.17	20.17	Residue chiefly silica with some other insoluble matter.
....	....	59.00	33.06	39.00	18.65	Insoluble residue not weighed.
0.48	0.16	90.80	50.88	6.87	3.28	
1.10	0.12	86.80	48.64	11.60	5.81	
2.78	0.56	77.60	43.49	17.41	8.32	
0.81	0.41	95.00	53.24	3.86	1.84	
1.86	0.62	86.96	48.73	10.08	4.82	
0.70	....	98.10	54.97	0.63	.30	

**Rominger, Mich. Geol. Surv., Vol. III, Pt. I, 1873, pp. 28, 29, 31.
††Residue insol. in HCl.
NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan

PRESQUE ISLE

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
464	Secs. 22, 23, 24, 25, 26, T. 35 N., R. 5 E., Rogers and Calcite.	Dundee limestone, upper 50 ft.	Drill cores...........	Mich. Limestone & Chemical Co.
465	Calcite quarry, Michigan Limestone & Chem. Co.	Dundee limestone. Quarry product as shipped in 1914.	Average of cargo analyses for 1914.	C. D. Bradley, July 20, 1915.
466	Rogers, Presque Isle Co.	Dundee limestone....	Composite of 27 hand specimens from surface.	*Arthur Uddenburg..
467	Calcite quarry, Mich. Limestone & Chem. Co.	Washed screenings....	Washed screenings....	G. F. Harris, Mich. Limestone & Chem. Co.
468	Rogers........	Dundee limestone....	....	J. G. Dean..........
469	to 667, see text.			
668	At lake level near old brewery, Calcite quarry, Mich. Limestone & Chem. Co.	Top of Monroe (?) formation just at water level.	Hand specimens......	Geo. F. Harris, Mch. Limestone & Chem. Co.
669	Gorge on E. branch Rainy River, SE¼ sec. 26, T. 35 N., R. 2 E.	Gray bituminous and fossiliferous limestone. Section about 12 ft.	Hand specimens......	R. C. Banks, Lab Univ. of Mich., 1915
670	Falls of Ocqueoc River, SW¼ SE¼ sec. 22, T. 35 N., R. 3 E.	Brown and black bituminous limestone with very fossiliferous horizons.	Hand specimens......	Same as above.......

*Ann. Rept. 1904, Mich. Geol. Surv., p. 124.

SCHOOLCRAFT

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
671	Manistique quarry, White Marble Lime Co.	Upper blue colored strata, not suitable for burning lime.	Anhydrous lime......	White Marble Lime Co.
672	Same as above.	Upper blue colored strata?	Rock sample.........	Lake Superior Iron & Chemical Co.
673	Same as above.	Lowest bed quarried. Light buff very crystalline and fossiliferous dolomite with drusy cavities; 8 ft. thick.	Rock sample.........	U. S. Geol. Surv., 1909
674	Same as above.	Same as above.......	Rock sample.........	L. C. Nodell & C. K. Wirth, Lab. Univ. of Mich., 1914.

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
0.34	....		97.85	*54.84*	1.26	*.60*	Average of 235 analyses of drill cores from an area of about 2 sq. miles.
0.51	0.38		97.38	54.52	1.81	0.81	Analyses furnished by C. D. Bradley, Gen. Mgr. Mich. Limestone & Chem. Co.
....	....		97.83	*54.83*	1.29	*.62*	Data furnished by F. D. Larke, Rogers, Mich.
0.50	0.40		97.54	54.62	1.55	.75	Analysis furnished by Mich. Limestone & Chem. Co.
0.62	0.20		98.34	*55.11*	0.45	*.21*	
0.30	0.30		91.38	51.17	8.01	3.83	Samples collected by G. F. Harris, Sept. 14, 1914.
2.84	1.65		92.97	*52.10*	2.27	*1.08*	
0.33	1.44		63.52	*35.60*	34.74	*16.62*	

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
1.14	0.54		57.00	*31.94*	39.87	*19.07*	Analysis furnished by Geo. J. Nicholson, Jr., White Marble Lime Co.
2.10	0.40		64.72	*36.27*	33.75	*16.14*	
1.92	0.30	0.03	54.04	*30.29*	*43.81*	*20.96*	
0.93	0.51		*54.83*	30.73	*45.45*	21.74	Sample collected by Mich. Geol. Survey, 1913.

NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan

SCHOOLCRAFT

Analysis No.	Location of quarry or deposit.	Name, thickness, and character of bed.	Kind of sample.	Analyst or authority.
675	Marblehead quarry, secs. 35 and 36, T. 42 N., R. 15 W., White Marble Lime Co.	Massive yellowish white to bluish gray mottled crystalline dolomite much like the Engadine dolomite; 8 ft. thick.	Rock sample.........	U. S. Geol. Surv., 1909
676	Same as above.	Same as above.......	Rock sample.........	White Marble Lime Co., Manistique.
677	Same as above.	Same as above.......	Rock sample.........	Same as above.......
678	Same as above.	Same as above.......	Rock sample.........	Same as above.......
679	Same as above.	Same as above.......	Rock sample.........	L. C. Nodell & C. K. Wirth, Lab. Univ. of Mich., 1914.
680	Blaney quarry 2¼ mi. N. of Blaney Jc., sec. 3, T. 42 N., R. 13 W., White Marble Lime Co.	Fiborn limestone, gray to buff lithographic limestone with disseminated calcite crystals, 26 ft. thick.	Composite sample of 5 rock specimens.	Same as above.......
681	Same as above.	Fiborn limestone, gray to buff lithographic limestone with small disseminated calcite crystals. Upper 10 ft., five different beds.	Rock specimens......	Lake Superior Iron & Chemical Co.,‡ 1906
682	Same as above.	Same as above.......	Rock specimens......	Same as above.......
683	Same as above.	Same as above.......	Rock specimens......	Same as above.......
684	Same as above.	Same as above.......	Rock specimens......	Same as above.......
685	Same as above.	Same as above.......	Rock specimens......	Same as above.......
686	Same as above.	Fiborn limestone, upper 10 feet.	Rock specimens......	U. S. Geol. Surv., 1909.‡
687	Same as above.	Fiborn limestone, first 8 ft.	Anhydrous lime......	D. E. Frauenfelder, Lake Superior Lime & Chem. Co., 1910.
688	Same as above.	Fiborn limestone, second 10 ft. from top of quarry.	Anhydrous lime......	Same as above.......
689	Same as above.	Floor of quarry. White coarsely crystalline dolomite, 3 ft. thick, not quarried.	Rock specimens......	L. C. Nodell & C. K. Wirth, Lab. Univ. of Mich., 1914.
690	Ridge 2 mi. N W. Hunt Spur SW¼ SW¼ sec 1, T. 42 N., R. 13 W. Guy D. Welton property.	Fiborn limestone gray to buff lithographic limestone with disseminated calcite crystals, 5 ft. terrace.	Rock specimens......	Same as above.......
691	Same as above.	Fiborn limestone.....	Rock specimens......	L. D. Frauenfelder Lake Superior Iron & Chemical Co.
692	Cave 2 mi. NW of Hunt Spur	Fiborn limestone gray to buff lithographic limestone with disseminated calcite crystals, 12 –ft.	....	Union Carbide Co....
693	Same as above.	Fiborn limestone.....	Rock specimens......	L. D. Frauenfelder, Lake Superior Iron & Chemical Co.
694	Ridge 2 mi. NW of Hunt Spur	Fiborn limestone.....	Rock specimens......	Same as above.......
695	Road cut 5 mi. N. of Whitedale, 40 rods W. of SE. cor. sec. 2, T. 42 N., R. 14 W.	Fiborn (?) limestone. Gray to buff lithographic limestone, 1 ft. exposure.	Weathered rock specimens.	L. C. Nodell & C. K. Wirth, Lab. Univ. of Mich., 1914.

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
0.56	0.20	0.06	55.00	*30.82*	44.31	*21.19*	
†0.05	0.16		57.28	*32.10*	39.86	*19.07*	Analysis furnished by Geo. J. Nicholson, Jr., White Marble Lime Co., Manistique.
1.80	0.90		52.40	*29.37*	44.65	*21.36*	
1.50	0.40		55.24	*30.96*	41.02	*19.62*	Samples from NE side of quarry. Stone solid blue in color.
1.83	*0.84		*54.76*	30.69	*45.74*	21.88	Samples collected by Mich. Geol. Surv., 1913.
0.77	*0.91		*95.87*	53.73	*3.76*	1.80	Same as above.
0.60	0.61		95.98	*53.79*	2.70	*1.29*	
1.40	trace		97.50	*54.64*	1.00	*.48*	
0.25	0.36		97.93	*54.88*	0.38	*.18*	
0.56	0.26		94.73	*53.09*	3.82	*1.83*	
1.30	0.28		93.00	*52.12*	5.14	*2.46*	
1.23	0.50	0.19	94.38	*52.89*	3.74	*1.79*	
1.50	0.94		......	94.92	......	1.70	This and the following analysis furnished by Geo. J. Nicholson, Jr., White Marble Lime Co.
1.60	1.16		......	92.16	......	1.91	Same as above.
0.72	*0.50		*59.58*	33.39	*41.66*	19.93	Samples collected by Mich. Geol. Surv., 1913.
1.66	*0.29		97.28	51.90	*1.61*	0.77	Analysis furnished by Guy D. Welton, Hunt Spur, Mich.
0.86	0.70		97.92	*54.87*	1.36	*.65*	Analysis furnished by Geo. J. Nicholson, Jr., White Marble Lime Co., Manistique.
1.64	*0.37		97.07	51.90	*1.88*	0.90	Analysis furnished by Guy D. Welton, Hunt Spur, Mich.
1.28	0.66		95.26	*53.38*	22.55	*1.22*	Analysis furnished by Geo. J. Nicholson, White Marble Lime Co., Manistique.
0.40	0.26		97.92	*54.87*	1.12	*.53*	Same as above.
0.67	*0.40		*89.76*	55.35	*2.59*	1.24	Samples collected by Mich. Geol. Surv., 1913.

*R_2O_3=iron, alumina, etc.
†Insoluble in HCl.
NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan

SCHOOLCRAFT

Analysis No.	Location of quarry or deposit.	Name, thickness and character of bed.	Kind of sample.	Analyst or authority.
696	Quarry 5 mi. N, 2 mi. E. of Whitedale, sec. 6, T. 42 N., R. 12 W.	White crystalline limestone, 6 to 8 ft. thick	Rock specimens......	Same as above.......
697	Same as above.	White crystalline laminated limestone, lowest bed quarried, 2 – ft. thick.	Rock specimens......	Same as above.......
698	Cooks, near cen sec. 20, T. 41 N., R. 17 W.	Yellowish to bluish white drusy and very crystalline dolomite underlying dense grained dolomite, 6 ft. ledge.	Hand specimens......	Same as above.......
699	1¼ mi. N. Cooks SW cor. sec. 17, T. 41 N., R. 17 W.	White very crystalline dolomite. Low ledge crossing road.	Hand specimens......	Same as above.......
700	Bluff 60 ft. high W½ cor. sec. 9, T. 42 N., R. 14 W.	Top white crystalline dolomite 12 ft. thick	Hand specimens......	Same as above.......
701	Same as above.	Thin bedded light gray crystalline dolomite 20 ft. from top of bluff.	Hand specimens......	Same as above.......
702	Same as above.	30 ft. from top of bluff.	Hand specimens......	Same as above.......

limestones by counties.

COUNTY.—*Con.*

Silica. SiO_2.	Iron. Fe_2O_3.	Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
1.45	*0.81		*73.08*	40.96	*26.21*	12.54	Same as above.
1.74	0.54		*89.87*	50.37	*5.23*	2.50	Same as above.
0.66	*0.21		*54.44*	30.51	*45.63*	21.83	Samples collected by R. A. Smith, Mich. Geol. Surv., 1913.
2.34	*0.41		*54.16*	30.35	*45.74*	21.88	Same as above.
0.45	0.62		*58.35*	32.70	*44.11*	21.10	Same as above.
1.54	1.33		*54.05*	30.29	*43.10*	20.62	Same as above.
1.13	1.31		*54.79*	30.71	*45.61*	21.82	Same as above.

*R_2O_3=alumina, iron, etc.
NOTE: Figures in italics calculated from original analyses.

Analyses of Michigan

WAYNE

Analysis No.	Location of quarry or deposit.	Name, thickness and character of bed.	Analyst or authority.
703	Gibraltar quarry, NW¼ SE¼ sec. 35. T. 4 S., R. 10 E.	Dolomite. Top 2 ft.	G. F. Ranson.
704	Same as above.	Hard blue dolomite. Next 4 ft.	Geo. F. Ranson.
705	Same as above.	Soft brown dolomite. Next 15 ft.	Geo. F. Ranson.
706	Same as above.	Soft brown dolomite. Bottom bed.	Geo. F. Ranson.
707	Sibley quarry, Solvay Process Co.	1. 6-ft. Top yellow brown to gray, thin bedded, very fossiliferous.	K. J. Sundstrum, Sibley Quarry Co.
708	Same as above.	2. 7-ft. Thin bedded, gray to bluish.	Same as above.
709	Same as above.	3. 2-ft. Compact, gray, rich in fossils.	Same as above.
710	Same as above.	4. 5-ft. Compact, crystalline, blue where fresh.	Same as above.
711	Same as above.	5. 6-ft. Compact, gray to blue, fossil fragments abundant. 6. 14-in. "Flint." Bluish gray chert, some fossils.	Same as above.
712	Same as above.	7. 6-ft. Gray to bluish, more heavily bedded.	Same as above.
713	Same as above.	8. 2-ft. "F int." Very brittle impure chert, some fossils.	Same as above.
714	Same as above.	9. 9-ft. Compact, heavily bedded, blue to gray. Locally contains over 98 per cent $CaCO_3$.	Same as above.
715	Same as above.	10. 6-ft. "Magnesian." Similar to 9 but oily and fossiliferous.	Same as above.
716	Same as above.	11. 8-ft. Gray, thin bedded, fossiliferous. 12. 12-ft. "Lower Magnesian." Ligh. to dark gray, fossiliferous. 13. 7-ft. "Siliceous." Thin bedded, firm, poor in fossils.	Same as above.
717	Sibley quarry, Solvay Process Co.	9. As above.	Same as above.
718	Same as above.		
719	Same as above.	7. As above. "Kiln bed".	Same as above.
720	Same as above.	4. As above.	Same as above.
721	Same as above.	2. 7-ft. bed, west bank.	Same as above.
722	Same as above.	1. 6-ft. bed, top, west bank.	Same as above.
723	Same as above.	7. 6-ft. lower, west side.	Same as above.
724	Same as above.	7. 6-ft. lower, south side.	Same as above.

limestones by counties.

COUNTY.

Silica. SiO_2.	Iron. Fe_2O_3. / Alumina. Al_2O_3.	Calcium carbonate. $CaCO_3$.	Calcium oxide. CaO.	Magnesium carbonate. $MgCO_3$.	Magnesium oxide. MgO.	Remarks.
*0.56	0.44	54.72	30.66	44.18	21.13	
*4.07	0.85	52.88	29.62	42.00	20.09	Insoluble residue.
0.80	0.54	56.68	31.76	40.00	19.13	
0.76	0.56	56.00	31.38	40.62	19.43	Crystals of celestite ($SrSO_4$) very noticeable in all but top beds.
1.82	0.34	91.75	51.42	2.52	1.20	
1.92	0.28	92.00	51.56	4.62	2.21	
1.04	trace	94.50	52.96	3.36	1.60	
1.08	trace	93.50	52.40	4.20	2.00	
2.24	0.58	87.00	48.75	9.45	4.52	
....	....	......	......	......	......	
2.56	0.20	85.75	48.05	10.29	4.92	Beds in Sibley quarry from top down.
30.87	3.45	53.50	29.98	12.18	5.82	
0.64	1.12	93.50	52.40	2.73	1.30	
3.74	0.74	74.00	41.47	20.58	9.84	
1.62	0.16	87.00	48.75	9.66	4.62	
....	....	......	......	......	......	
....	....	......	......	......	......	
0.91	1.86	94.00	52.68	2.10	1.00	
....	....	92.60	51.89	5.40	2.58	
2.96	traces	94.40	52.90	2.18	1.04	
1.08	2.90	91.15	51.08	4.87	2.32	Dried sample.
1.06	2.85	89.70	50.27	4.80	2.29	
2.00	2.50	86.79	48.64	6.80	3.25	
2.88	2.71	80.36	45.03	14.05	6.72	
2.29	6.60	81.95	45.92	7.20	3.44	

*Insoluble in HCl.

MISCELLANEOUS NON-METALLIC MINERALS.

COAL.*

Coal mining began in Michigan as early as 1835 but no records of production were kept until 1860, when Michigan was credited with an output of 2,320 tons. Ten years later the production reached 28,150 tons. In 1880, it was 100,800 tons and for the two following years it exceeded the 100,000 ton mark. A sharp decline began in 1883 and in 1884 the production fell to only 36,712 tons and it was not until 1895 that the production again exceeded 100,000 tons. In 1897 the Saginaw and Bay county coal fields were opened and the production reached 223,592 tons. After this the industry grew rapidly, the production in 1901 being 1,241,241 tons. The maximum production of 2,035,858 tons was attained in 1907. Since that year the production has gradually fallen until in 1915 it was only 1,069,672 tons.

Most of the coal is produced in Bay and Saginaw counties, these two counties in 1915 producing respectively 503,002 and 511,184 tons or together 94.5 per cent of the total output of the state. The decrease is chiefly due to competition from higher grade and more cheaply mined coals from Ohio, Pennsylvania and West Virginia. The average cost of mining coal in Michigan, (see table) from 1910 to 1914 inclusive ranged from $1.89 to $1.99 per ton. The cost in Ohio averages less than $1.00 per ton. The Michigan operator is protected by differential freight rates varying from $.75 to $1.40 per ton for coals from Ohio and about $.25 additional for coals from West Virginia. The lower cost of mining, however, enables the Ohio and West Virginia operators to deliver coal at most points in the southern part of the Southern Peninsula at prices ruinous to the Michigan operators. In addition the Ohio coals are of higher average quality.

The markets of the Michigan operators are largely restricted to the central and northern portions of the state. Prior to 1903, less than 10 per cent of the coal was mined by coal cutting machines. Five years later, the percentage had increased to 29.2 per cent, in 1910 to 45.5 per cent, in 1914 and 1915 to 77.8 per cent and 76.1 per cent respectively.

Up to 1904, the coal cutting machines were chiefly of the pick or puncher type. The chain breast machines were then introduced but this type was not so widely used as the pick or puncher type for it is

*For a more complete report of the coal industry in Michigan see Publication 19 (Geol. Ser. 16), Mineral Resources of Michigan for 1914.

not well adapted to the thin coal seams and the weak roofs which obtain in Michigan. The so-called short wall machine was introduced in 1910 with such success that it threatens to displace all other types.

The problem of the Michigan operators is to reduce mining costs. In 1915 the average cost per ton of coal mined was $1.77, or $.22 less than in 1914. This decrease is said to be due largely to the introduction of more efficient types of the short wall coal cutting machines.

PRODUCTION, COST OF MINING, AND VALUE OF COAL IN MICHIGAN, 1900-1915.

YEAR.	*Number active mines.	Average number employees per month.	**Average daily wage.	Total tons of coal mined.	Total cost of coal mined.	Average cost per ton.	***Total tons of coal mined.	***Total value of coal mined.	***Average price received per ton.	Profit made per ton.
1900	31	1,676	$2 34	871,388	$1,209,228	$1.387	849,475	$1,259,683	$1.483	$0.096
1901	30	1,847	2 44	1,016,496	1,442,415	1.419	1,241,241	1,753,064	1.412	.007
1902	32	1,616	2 75	899,967	1,284,342	1.427	964,718	1,653,192	1.714	.287
1903	34	3,014	2 91	1,601,984	2,529,027	1.579	1,367,619	2,707,527	1.979	.400
1904	33	2,733	3 01	1,408,375	2,266,098	1.609	1,342,840	2,424,935	1.806	.197
1905	38	2,776	2 96	1,413,307	2,244,434	1.588	1,473,211	2,512,697	1.705	.117
1906	38	2,106	2 40	1,367,385	2,090,489	1.529	1,346,338	2,427,404	1.803	.274
1907	37	2,897	3 24	1,911,201	3,162,837	1.655	2,035,858	3,660,833	1.708	.143
1908	38	3,115	3 02	1,842,778	3,089,759	1.677	1,835,019	3,322,904	1.811	.134
1909	36	2,907	2 93	1,736,573	2,865,083	1.650	1,784,692	3,199,351	1.793	.143
1910	34	2,471	3 07	1,462,276	2,626,342	1.796	1,534,967	2,930,771	1.909	.103
1911	32	2,539	3 39	1,389,585	2,623,244	1.887	1,476,074	2,791,461	1.891	.004
1912	26	1,886	3 19	1,160,768	2,170,076	1.869	1,201,230	2,399,451	1.989	.120
1913	24	2,076	3 49	1,138,163	2,250,559	1.977	1,231,786	2,455,227	1.993	.016
1914	23	2,146	3 35	1,153,869	2,285,281	1.99	1,283,030	2,559,786	1.99	.000
1915	20	1,942	3 45	1,069,798	1,929,386	1.77	....	....	....	....

*Compiled and adapted from reports of State Coal Mine Inspector, Ann. Repts. State Department of Labor.
**For year beginning Dec. 1 and ending Nov. 30.
***From Mineral Resources of United States, U. S G. S.

PRODUCTION OF COAL BY COUNTIES, 1899-1915.

	Bay.	Eaton.	Ingham.	Jackson.	Saginaw.	Shiawassee.	Tuscola.	Other counties.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
*1915	503,002	a	a	a	511,184	a	a	55,612
*1914	540,319	82	1,376	1,287	545,165	903	†45,195	.....
*1913	579,123	155	2,953	457	521,848	2,170	31,480	453
*1912	607,740	374	3,874	....	489,198	4,532	59,252	......
1911	766,470	100	....	....	667,282	13,000	66,427	19,000
1910	766,470	100	....	....	667,282	....	....	101,215
1909	822,577	558	....	1,500	859,434	....	....	100,623
1908	782,503	2,286	....	5,539	999,338	....	....	45,353
1907	962,574	5,982	....	5,645	1,047,927	....	....	13,730
1906	481,398	18,507	....	8,658	835,475	....	....	2,300
1905	544,154	4,058	....	9,196	915,803	....	....	....
1904	410,634	9,057	....	16,860	906,289	....	....	....
1903	325,021	7,393	....	23,307	1,011,898	....	....	....
1902	248,645	8,800	....	23,889	670,304	....	....	13,400
1901	253,821	4,803	....	20,288	938,042	....	....	24,284
1900	190,814	4,530	....	23,317	601,112	....	....	....
1899	104,588	3,421	....	21,600	455,607	....	....	39,492

*Compiled from Annual Report of State Department of Labor.
†Incomplete returns, tonnage approximate.
(a) Included in other counties.

PRODUCTION OF COAL IN MICHIGAN, 1860-1915, IN SHORT TONS.

Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.	Year.	Quantity. Tons.
1860	2,320	1871	32,000	1882	135,339	1893	45,979	1904	1,342,840
1861	3,000	1872	33,600	1883	71,296	1894	70,022	1905	1,473,211
1862	5,000	1873	56,000	1884	36,712	1895	112,322	1906	1,346,338
1863	8,000	1874	58,000	1885	45,178	1896	92,882	1907	2,035,858
1864	12,000	1875	62,500	1886	60,434	1897	223,592	1908	1,835,019
1865	15,000	1876	66,000	1887	71,461	1898	315,722	1909	1,784,692
1866	20,000	1877	69,197	1888	81,407	1899	624,708	1910	1,534,967
1867	25,000	1878	85,322	1889	67,431	1900	849,475	1911	1,476,074
1868	28,000	1879	82,015	1890	74,977	1901	1,241,241	1912	1,164,973
1869	29,980	1880	100,800	1891	80,307	1902	964,718	1913	1,138,639
1870	28,150	1881	112,000	1892	77,990	1903	1,367,619	1914	1,283,030
								*1915	1,069,798

*Report of State Coal Mine Inspector, State Department of Labor.

PRODUCTION OF COAL, COST OF MINING, ETC., IN MICHIGAN BY COUNTIES AND MONTHS FOR 1915.[1]

January.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per month.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	6	997	7.8	19.2	$3 81	$73,019 16	6	991	15,371	35,040	50,411	$1 98	$100,167 01
Saginaw	8	934	7.8	17.0	3 40	54,085 66	8	760	15,394	25,029	40,423	1 85	74,865 64
Calhoun, Eaton, Genesee, Ingham, Jackson, Tuscola	6	200	8.0	22.2	3 22	14,300 80	1	157	1,547	4,463	6,010	1 92	11,780 94
Total	20	2,131	7.9	18.5	$3 58	$141,405 62	15	1,908	32,312	64,532	96,844	$1 92	$186,713 59

February.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per month.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	5	893	7.9	16.3	$3 69	$53,747 94	5	763	9,165	27,052	36,217	$2 03	$73,650 53
Saginaw	7	858	7.9	16.9	3 24	47,115 53	7	576	12,679	22,860	35,539	1 75	62,386 32
Calhoun, Eaton, Genesee, Ingham, Tuscola	5	205	8.0	23.3	3 24	15,527 28	1	126	1,433	3,790	5,223	1 98	10,321 46
Total	17	1,956	7.9	17.3	$3 43	$116,390 75	13	1,465	23,277	53,702	76,979	$1 90	$146,358 31

[1]Adapted from the Report of the State Coal Mine Inspector, Ann. Rept. State Department of Labor for 1915.

March.													
Bay	5	851	7.7	17.7	$3 67	$55,423 50	5	581	7,295	33,703	40,998	$1 87	$76,717 73
Saginaw	7	1,014	7.9	16.1	3 17	51,858 93	7	659	12,146	24,728	36,874	1 93	71,388 59
Calhoun, Genesee, Ingham, Tuscola	4	194	8.0	21.6	3 24	13,571 40	1	104	854	3,587	4,441	1 98	8,821 25
Total	16	2,059	7.9	17.3	$3 39	$120,853 83	13	1,344	20,295	62,018	82,313	$1 81	$156,927 57
April.													
Bay	5	690	7.9	18.1	$3 71	$46,351 10	4	620	5,512	29,124	34,636	$1 77	$61,447 64
Saginaw	5	764	7.8	14.9	3 26	37,170 31	5	489	8,484	18,320	26,804	1 87	50,134 27
Genesee, Ingham, Tuscola	3	186	8.0	19.5	3 23	11,755 58	1	82	688	1,970	2,658	1 93	5,147 86
Total	13	1,640	7.9	16.8	$3 45	$95,276 99	10	1,191	14,684	49,414	64,098	$1 82	$116,729 77
May.													
Bay	5	729	7.9	14.9	$3 79	$41,248 46	4	466	7,529	23,538	31,067	$1 84	$57,366 46
Saginaw	6	845	7.9	15.4	3 33	43,361 91	6	590	5,662	26,311	31,973	1 85	57,404 79
Calhoun, Genesee, Ingham, Tuscola	4	180	8.0	21.6	3 23	12,554 50	1	36	883	1,199	2,082	1 86	3,878 17
Total	15	1,754	7.9	15.8	$3 50	$97,164 87	11	1,092	14,074	51,048	65,122	$1 85	$120,649 42

PRODUCTION OF COAL, COST OF MINING, ETC., IN MICHIGAN BY COUNTIES AND MONTHS FOR 1915.—*Continued.*

June.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per month.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	4	601	7.8	20.6	$3 23	$40,072 24	4	553	7,160	36,980	44,140	$1 37	$60,887 46
Saginaw	6	878	7.9	15.1	3 38	44,930 20	6	512	8,927	36,378	45,305	1 38	62,868 75
Calhoun, Genesee, Ingham, Shiawassee, Tuscola	5	215	8.0	18.7	3 72	14,995 38	1	125	1,611	2,683	4,294	1 86	8,022 04
Total	15	1,694	7.9	17.5	$3 37	$99,997 82	11	1,190	17,698	76,041	93,739	$1 40	$131,778 25

July.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per month.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	4	595	7.9	17.3	$3 56	$36,657 07	4	395	16,648	8,916	25,566	$2 17	$55,494 67
Saginaw	6	875	7.9	17.3	3 31	50,166 08	6	610	7,803	31,463	39,266	1 73	68,289 55
Calhoun, Genesee, Ingham, Shiawassee, Tuscola	5	230	8.0	18.7	3 72	15,981 14	1	98	1,391	2,993	4,384	1 85	8,126 53
Total	15	1,700	7.9	17.5	$3 45	$102,804 29	11	1,103	25,842	43,372	69,214	$1 90	$131,910 75

August.

Bay	5	817	7.9	19.5	$3 51	$56,071 80	5	648	11,841	27,813	39,654	$2 01	$79,817 04
Saginaw	6	877	7.9	17.3	3 47	52,780 94	6	586	8,826	33,140	41,966	1 74	73,054 97
Genesee, Shiawassee, Tuscola	3	245	8.1	22.7	3 41	18,975 00	1	92	1,197	3,170	4,367	1 86	8,132 72
Total	14	1,939	8.0	18.9	$3 48	$127,827 74	12	1,326	21,864	64,123	85,987	$1 87	$161,004 73

September.

Bay	5	856	7.9	19.5	$3 50	$58,423 44	5	733	10,858	29,605	40,463	$1 96	$79,376 09
Saginaw	6	891	7.8	21.3	3 31	62,737 38	6	757	8,721	40,820	49,541	1 61	80,045 55
Genesee, Shiawassee, Tuscola	4	246	8.0	21.2	3 51	17,826 30	1	85	1,413	3,980	5,393	1 92	10,369 50
Total	15	1,993	7.9	20.4	$3 41	$138,987 12	13	1,590	20,992	74,405	95,397	$1 77	$169,791 14

October.

Bay	5	898	7.9	20.7	$3 50	$64,963 56	5	696	10,669	33,117	43,786	$2 02	$87,661 52
Saginaw	6	894	7.9	21.3	3 10	59,042 74	6	729	7,700	43,069	50,769	1 65	84,055 06
Genesee, Shiawassee, Tuscola	3	237	8.0	21.7	3 25	16,692 90	1	73	1,149	3,907	5,056	1 89	9,598 12
Total	14	2,029	8.0	21.1	$3 28	$140,699 20	12	1,498	19,518	80,093	99,611	$1 82	$181,314 70

PRODUCTION OF COAL, COST OF MINING, ETC., IN MICHIGAN BY COUNTIES AND MONTHS FOR 1915.—*Concluded.*

November.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per month.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	6	1,024	7.9	19.9	$3 73	$76,052 01	6	937	10,667	41,004	51,671	$1 95	$100,196 70
Saginaw	7	935	7.9	21.3	3 45	68,842 81	7	719	7,066	47,751	54,816	1 66	91,075 35
Eaton Genesee Ingham Shiawassee Tuscola	5	247	8.0	20.8	2 85	13,737 89	1	76	1,326	4,207	5,533	1 89	10,474 09
Total	18	2,206	7.9	20.6	$3 51	$159,568 71	14	1,732	19,058	92,062	111,120	$1 82	$202,746 14

December.

County.	Number of active mines.	Number of employees.	Average number of hours worked per day.	Average number of days worked per month.	Average daily wages.	Aggregate amount paid in wages.	Number of mines using powder.	Number of kegs used.	Number of tons of picked coal mined.	Number of tons of machine coal mined.	Total number of tons of coal mined.	Average cost per ton.	Total cost of output.
Bay	6	1,029	7.9	25.0	$3 62	$92,431 83	6	1,070	17,772	46,621	64,393	$1 87	$120,169 67
Saginaw	7	939	8.0	23.1	3 44	73,800 89	7	803	6,478	52,336	58,814	1 59	93,523 64
Eaton Genesee Ingham Shiawassee Tuscola	4	238	8.0	25.1	3 24	19,350 70	3	156	1,505	4,662	6,167	1 58	9,767 89
Total	17	2,206	7.9	24.3	$3 48	$185,583 42	14	2,029	25,755	103,619	129,374	$1 72	$223,461 20
Grand total	....	1,942	7.9	18.7	$3 45	$1,526,560 36	......	17,468	255,369	814,429	1,069,798	$1 76	$1,920,385 57

GROWTH OF LIMESTONE INDUSTRY.

The limestone industry in Michigan made a relatively rapid growth after 1899, but the period of most rapid growth was after 1904. In 1899 the total value of the product including lime was only $281,769, while in 1915 the total value exclusive of lime, which amounted to $349,979, was $828,766. The total value of lime and limestone products in 1915 was 7.7 times that in 1899. The gain, exclusive of lime, in 1915 was $370,805, or 25.4 per cent.

The chief increases were in stone for blast furnace flux, the manufacture of soda ash and allied products, and for concrete and railway ballast. The production of flux stone in 1910 was only 341,027 tons valued at $186,046; in 1915 it was 2,254,984 tons valued at $763,029. The increase for five years was 561 per cent in quantity and 310 per cent in value. The large increase in flux stone in 1915 was due to the general industrial prosperity and the development of large deposits of high grade limestone in the northern part of the state very suitable for blast furnace use. This stone is successfully invading the flux stone markets formerly dominated by limestone from other states.

The chief decreases were in crushed stone for roadmaking and stone for sugar manufacture.

Twenty-six quarries were in operation in 1915. Some quarries, chiefly small ones, were idle but the loss was compensated by the opening of new or the reopening of old quarries. The Great Lakes Stone & Lime Co. completed their crushing plant at Rockport and began active operation in 1915. Their stone is high calcium limestone, bituminous, and very fossiliferous. The Cheboygan Limestone Products Co. opened a quarry near Mackinac City in high calcium beds belonging to the Dundee limestone.

Owing to the purity and favorable situation of the limestone deposits near water, in which the more recent and larger quarries have been opened, it is very probable that the limestone industry in Michigan will continue to make a steady and rapid growth. With the return of more normal conditions in the iron industry, the season of 1915 proved to be the greatest in the history of the limestone industry in Michigan.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1915.

Year.	Rough building. Value.	Dressed building. Value.	Paving. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone. Road making. Tons.	Crushed stone. Road making. Value.
1899	$30,299	*	$62,815	....	....	....	$1,111	....	....
1900	32,362	*	105,266	....	....	....	799	....	....
1901	47,785	*	....	*	$380	$5,098	*	....	$31,605
1902	58,707	*	....	$489	200	3,101	5,740	....	56,261
1903	36,528	*	49,000	250	5,150	710	800	....	61,342
1904	32,941	$805	37,665	....	....	2,800	2,405	....	58,655
1905	17,071	....	....	160	....	744	1,568	....	112,113
1906	9,368	641	90,723	75	....	4,654	1,204	....	78,437
1907	15,120	100	56,500	....	....	1,433	1,234	....	131,708
1908	7,276	....	10,825	300	100	15,907	1,574	....	182,510
1909	4,450	7,445	....	....	....	1,572	3,615	....	132,902
1910	3,522	....	35,500	....	....	2,205	908	....	110,184
1911	7,526	....	....	....	....	165	380	$224,307	113,574
1912	9,997	....	....	....	....	380	75	603,553	295,449
1913	8,274	....	....	....	....	3,511	610	532,311	266,316
1914	3,537	....	....	....	....	1,651	6,727	505,133	242,839
1915	4,262	....	*	....	....	743	104	482,262	194,970
Total	$329,055	....	....	....	....	$44,674	$28,854	....	$2,068,865

*Included in total for year.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1915.—*Continued.*

Year.	Crushed stone.				For blast furnace flux.		To sugar factories.	To alkali works.
	Railroad ballast.		Concrete.					
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Value.	Value.
1899						$27,512		
1900						3,200		
1901		$18,200		$75,643		13,488		
1902		40,810		49,430		32,246		
1903		35,340		48,504		15,502		
1904		57,100		60,745		62,586		
1905		43,649		107,396		109,883		
1906		103,442		61,852		81,517	$224,356	
1907		46,516		97,762		109,429	22,234	
1908		33,900		73,200		56,841	32,594	
1909		42,445		112,829		91,915	25,845	
1910		42,358		178,318		100,149	69,647	
1911	91,713	34,998	306,385	137,285	341,027	186,046	65,141	*
1912	54,327	28,368	185,423	97,298	295,941	137,812	36,944	$508,044
1913	116,000	48,400	292,616	145,965	1,202,817	494,495	38,215	320,961
1914	38,000	20,600	362,209	166,959	1,604,240	565,012	69,477	269,087
1915	60,159	19,640	398,948	217,304	2,254,984	763,029	46,143	481,759
Total		$615,766		$1,630,490		$2,850,662	$630,596	

*Concealed—included in total.

PRODUCTION AND VALUE OF LIMESTONE IN MICHIGAN, BY USES, 1899-1915.—*Concluded.*

Year.	To carbonic acid plants. Value.	To paper mills. Value.	Fertilizer. Tons.	Fertilizer. Value.	Other purposes.	To lime burners.	Rank of state. Value.	Total. Value.
1899	....	....	....	....	$2,375	$157,657	....	$281,769
1900	....	....	....	....	124,220	65,000	12	330,847
1901	....	....	....	....	101,399	136,173	12	429,771
1902	....	....	....	....	68,164	98,000	13	413,148
1903	....	....	....	....	4,747	132,600	14	390,473
1904	....	....	....	....	5,323	180,683	10	501,708
1905	....	....	....	....	142,790	9,380	12	544,754
1906	....	....	....	....	....	....	10	656,269
1907	....	....	....	....	278,297	....	11	760,333
1908	....	....	....	....	253,990	....	9	669,017
1909	....	....	....	....	327,571	....	11	750,589
1910	....	....	....	....	299,305	....	9	842,126
1911	....	$12,558	....	$3,003	440,857	....	8	1,005,751
1912	....	8,150	....	3,447	13,596	....	8	1,139,560
1913	....	10,723	....	7,048	395,874	....	7	1,408,703
1914	$53,138	8,307	$10,907	11,104	39,523	....	....	1,457,961
1915	*	8,620	....	9,746	31,529	....	....	1,828,766
Total	....	$48,358	....	$34,358	$2,529,560	....	....	$13,411,546

*Included in total.

GROWTH OF LIME INDUSTRY.

In the last ten years the lime industry in Michigan has made very little growth in comparison with the limestone industry. This is due to several causes, viz.: (1) the growing scarcity of cheap wood fuel for burning lime, (2) the substitution of concrete for stone and lime mortar in construction work, (3) the rapidly growing use of gypsum wall plaster and plaster substitutes, and (4) the unfavorable location of suitable limestone deposits. Formerly, owing to the abundance of wood fuel, lime was burned at many localities in the state, but now lime is produced only at Menominee, Manistique, Marblehead, and Rexton in the Northern Peninsula, and at Alpena, Afton, Petoskey, Bay Shore, and Charlevoix, and near Omer. No lime is burned in the southern half of the Southern Peninsula. Most of the exposures of limestone are in the northern part of the state relatively distant from large markets and the consequent high transportation charges make it difficult for Michigan operators to compete with lime producers in Ohio, Indiana, and Illinois, situated near cheap coal fuel supplies.

Concrete mortar is more easily and rapidly handled than stone and lime mortar and has largely replaced these materials in the building trades. For similar reasons, gypsum plasters and plaster board have replaced sand lime mortar for plastering.

Most of the lime produced is of the "hot" variety, but considerable mild magnesian lime is burned at Manistique, Marblehead, Petoskey, and Bay Shore. Hydrated lime is produced at Afton, Charlevoix, and Manistique.

The total production in 1915 was 81,359 tons valued at $349,979 as compared with 66,507 tons valued at $287,648 in 1914. This represents a gain of 22.3 per cent in quantity and 21.7 per cent in value. The average price in 1915 was $4.29 per ton, or $.04 less per ton than in 1914.

PRODUCTION AND VALUE OF LIME IN MICHIGAN, 1904-1915.

Year.	Total lime burned.		Average price per ton.	No. of plants operating.	Rank of state. Production.
	Quantity, Tons.	Value.			
1904	63,601	$256,955	$4 04	....	....
1905	48,089	192,844	4 01	....	....
1906	68,133	281,465	4 13	13	....
1907	65,822	276,534	4 20	12	16
1908	68,050	282,023	4 14	10	15
1909	83,108	354,135	4 26	12	13
1910	72,345	303,377	4 19	10	14
1911	80,709	352,608	4 37	14	14
1912	74,720	311,448	4 17	11	16
1913	77,088	331,852	4 05	10	14
1914	66,507	287,648	4 33	10	14
1915	81,359	349,979	4 29	10	....

SANDSTONE.

The value of the annual production of sandstone in Michigan decreased from $188,073 in 1902 to only $12,983 in 1911. In 1912 and 1913 there were slight increases, the total value of the output in each of these years being $16,438 and $19,224 respectively. In 1914 there was but one operator and in 1915, two, hence no figures on production and value are given.

The decline of the sandstone industry in Michigan may be ascribed (1) to the poor quality of much of the sandstone, (2) to the substitution of concrete in construction work and, (3) to the greater use of brick and artificial stone.

Quarries were formerly operated in Coal Measure sandstones near Ionia and Grand Ledge and at many places in the Marshall sandstone in Calhoun, Hillsdale, Jackson, and Huron Counties. Most of the sandstone in these formations, upon exposure to the weather for a few years, alters uniformly or in spots to an unsightly yellow color. The sandstone near Ionia, however, though soft and friable is streaked and mottled with red, orange, and yellow and makes a pleasing appearance in buildings. Some rubble and riprap incidentally are produced from the Lower Marshall by the Wallace Co. near Port Austin, Huron county.

The production of sandstone for 1915 was derived from the Jacobsville formation, apparently the local equivalent of the Lake Superior or Upper Cambrian sandstone, and from the Lower Marshall. Extensive quarrying operations have been carried on for a number of years near Jacobsville, Houghton county, but the Portage Entry Redstone Co. is now the only active operator. The "redstone" or "brownstone" of the Jacobsville sandstone is well cemented, permanent in color and

pleasing in appearance, but the great distance of the beds from markets is a serious obstacle to their development.

Formerly much sandstone was quarried for foundations but now concrete has largely replaced stone for such purposes because of the cheapness of concrete and the rapidity and ease with which it can be handled. Front and fancy brick are relatively cheap and very artistic effects may be obtained by their use. They have largely supplanted stone as a building material, and very probably the sandstone industry in Michigan will not regain its former importance.

*PRODUCTION AND VALUE OF SANDSTONE IN MICHIGAN, 1899-1915.

Year.	Rough building. Value.	Dressed building. Value.	Curbing. Value.	Flagging. Value.	Rubble. Value.	Riprap. Value.	Crushed stone. Road making. Value.	Crushed stone. Concrete. Value.	Other. Value.	Total. Value.
1899	$102,447	$51,682	$109	a					$23,800	$178,038
1900	73,850	58,800								132,650
1901	128,909				$26,519	b			19,000	174,428
1902	136,280	23,600			27,393	$800				188,073
1903	89,931	10,365			15,554		$2,050	$3,450		121,350
1904	47,593	14,818			10,657		1,400	400		74,868
1905	64,056	36,035			10,332				12,700	123,123
1906	35,272	18,950			10,403	770				65,395
1907	33,561	10,918		$528	7,900	96				53,003
1908	15,100	18,813			5,190					39,103
1909	12,985	16,805			6,294					36,084
1910	13,312	15,416			2,505					31,233
1911	5,682	2,809			3,068	1,140			286	12,985
1912	c	c			c	c			a	16,438
1913	c	c			c	3,127			c	19,224
1914	d	d			d	d				d
1915	d	d			d	d				d
Totals			$109					$3,850		

a Included under curbing.
b Included under rubble.
c Included in total.
d Figures not given—less than three operators.
*Exclusive of sandstone made into grindstones and scythestones.

GRINDSTONES AND SCYTHESTONES.

Although Michigan ranks second to Ohio in the production of grindstones and scythestones, the latter state produces about eight times as much as Michigan. The "grit" or "grindstone" occurs in the lower part of the Marshall formation in Huron county. The Wallace Company of Port Austin and the Cleveland Stone Company operate quarries at Eagle Mills and Grindstone City respectively, where the gritstone occurs in low-lying and thinly drift covered ledges near the shore of Lake Huron. The surface deposits are removed by stripping, and the stone is cut by channelling machines into square blocks eight feet or more in thickness. These are split with wedges along the bedding planes into thinner slabs which are loaded on cars by derricks, then taken to the mills for sawing into grindstones. The grindstones vary in size from very small ones a foot in diameter up to those seven feet in diameter with a 14-inch face. The broken stone is worked up into various grades of scythestones.

As there are but two producers no tables of production and value can be given.

SAND AND GRAVEL.

Michigan has very large sand and gravel resources. The most important deposits occur in the form of ridges known as "hogbacks" or eskers, in irregular hills, called kames, in out-wash plains and deltas, and in old beach ridges, features resulting from the last glacial invasion. Only a small portion of the sand and gravel resources have been developed. The chief developments are in the vicinity of cities, in river channels, and along the shores of the Great Lakes where means of transportation are favorable. Large pits are locally developed in building state award roads. The chief localities and counties in order of importance are: Detroit and St. Clair rivers and Kent, Washtenaw, Macomb, Ingham, Livingston, Manistee, Oakland, Berrien, Jackson, Kalamazoo, and Calhoun counties.

In 1915 Michigan produced 3,776,726 tons of sand and gravel valued at $1,036,739. This represents a gain of 18,747 tons and a loss of $107,032 in value. The chief increases in quantity were in glass and molding sand, engine sand, and gravel and the chief losses in building sand and paving sand. There were but two producers of glass sand in 1915, hence figures of production and value are not given.

PRODUCTION AND VALUE OF SAND AND GRAVEL IN MICHIGAN, 1904-1915.

Year.	Glass sand.		Molding sand.		Building sand.		Fire sand.		Engine sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.		Tons.	
1904...	......	......	167,147	$76,299	69,656	$30,898	.....	.....	......	......
1905...	......	......	19,382	13,247	263,315	148,065	5,000	$2,500	......	......
1906...	600	$3,000	61,387	26,108	403,199	127,937	.....	.....	4,000	$400
1907...	4,300	8,600	54,172	24,190	451,646	157,150	6,000	3,000	1,534	153
1908...	17,000	34,000	4,584	2,892	474,238	228,395	.....	.....	1,991	319
1909...	65,000	79,000	53,226	20,756	1,090,419	327,247	4,000	2,000	12,415	1,493
1910...	16,212	25,675	93,812	24,004	1,151,588	334,336	5,000	3,000	22,270	2,172
1911...	*	*	68,878	17,901	833,729	247,997	*	*	25,392	4,447
1912...	*	*	152,433	40,145	902,556	294,115	.....	.....	18,575	4,774
1913...	*	*	50,763	17,493	1,326,016	415,737	4,542	4,542	4,447	647
1914...	26,035	32,593	53,400	36,583	1,088,650	360,152	.....	.....	6,357	1,066
1915...	*	*	82,666	25,998	843,887	236,956	4,601	5,751	70,077	2,794
Totals..	......	......	861,851	$325,616	8,898,899	$2,918,985	.....	.....	167,058	$18,265

Year.	Furnace sand.		Paving sand.		Other sand.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.	
1904..........	....	....	....	....	....	....
1905..........	....	....	....	....	50,187	$14,476
1906..........	5,000	$2,500	....	....	51,005	12,140
1907..........	3,858	3,133	....	....	173,724	12,187
1908..........	3,329	3,828	....	....	29,187	6,850
1909..........	3,183	3,660	....	....	295,612	50,953
1910..........	3,185	4,924	....	....	372,880	57,385
1911..........	*	*	152,144	$29,650	114,801	52,005
1912..........	....	....	68,453	16,898	130,624	54,746
1913..........	†	†	533,261	108,328	113,318	20,342
1914..........	†	†	320,322	74,866	115,291	107,392
1915..........	....	....	131,466	14,021	111,105	12,248
Totals.....	....	....	1,205,646	$249,763	....	....

Year.	Railroad ballast.		Gravel.		Total.		Rank.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1904...	....	....	....	....	236,803	$107,197	....	....
1905...	....	....	76,625	$32,321	414,509	210,609	10	11
1906...	....	....	72,598	25,614	597,789	197,699	12	13
1907...	....	....	329,407	81,182	1,024,641	289,595	10	11
1908...	....	....	312,262	94,081	842,591	370,365	8	9
1909...	....	....	695,902	200,523	2,219,757	685,632	8	8
1910...	....	....	1,197,791	364,841	2,862,738	816,337	7	8
1911...	....	....	935,072	203,218	2,185,165	565,969	9	10
1912...	....	....	1,409,180	407,925	2,681,821	818,603	9	8
1913...	....	....	3,928,874	915,205	6,422,818	1,528,892	4	5
1914...	7,565	$781	2,140,359	530,338	3,757,979	1,143,771	8	7
1915...	....	....	2,457,094	671,970	3,776,726	1,036,739	....	....
Total...	....	....	13,555,164	$3,527,218	27,123,337	$7,771,408	....	....

*Included under other sand. †Included under fire sand.

SALT.

The amount and value of salt produced in Michigan in 1915 were greater than any previous year. The total quantity produced in 1915 was 12,588,788 barrels or 917,812 barrels more than in 1914. The value in 1915 was $4,304,731 or nearly $1,015,726 more than in 1914. The large gain was due not only to the increase in production but to a considerably higher average price per barrel. The average price in 1915 was $0.342 per barrel or $0.039 more than in 1914. Since 1905 the average price per barrel has risen from $0.196 per barrel to $0.342 per barrel.

From 1880 to 1892, Michigan held first rank in the United States in amount of production. In 1893, New York took first rank and held it continuously, with the exception of 1901, until 1905 when Michigan regained the leadership. Michigan has since held first rank with the exception of the years 1910 and 1911.

The center of the salt industry in Michigan thirty years ago was in Saginaw valley, especially along Saginaw river from Saginaw to Bay City. The industry was carried on in connection with the saw mills. More than 100 mills utilized their waste steam and fuel in evaporating natural brine obtained from the Upper Marshall sandstone. With the decline of the lumber industry in Saginaw valley, the salt industry has become relatively unimportant.

The chief salt producing districts are along the Detroit-St. Clair rivers and at Ludington and Manistee. In these districts artificial brines are obtained by forcing water through casings down to the salt beds and then back to the surface.

In 1915, Wayne county produced 6,977,500 barrels of salt valued at $1,088,507, or less than $0.16 per barrel. Much of the brine is used directly in the manufacture of soda ash, black caustic, etc., and this accounts for the abnormally low price of the salt per barrel. In 1915, St. Clair county produced 2,429,889 barrels of salt valued at $1,899,712, or over $0.78 per barrel. In this county, a large part of the product is table and dairy salt and this accounts for the abnormally high average price.

Rock salt is mined by the Detroit Rock Salt Co. at Oakwood, a small suburb on the west side of Detroit. The salt is obtained from a 20-foot bed at the depth of 1,040 feet. Much of the product is used in curing meats, fish, hides, and in the manufacture of ice cream.

In the Manistee-Ludington district, salt is made at Manistee and Filer City, Manistee county and at Ludington, Mason county. In this district, the salt is still made largely by the waste steam from lumber mills.

In 1915, this district produced 2,725,533 barrels of salt valued at $1,109,237 or about $0.246 per barrel. Most of the product is of the common fine and common coarse grades. Only one company produces table and dairy salt.

Bromine and bromides are produced from natural brines from the Marshall formation at Midland and Mt. Pleasant, and calcium chloride at Mt. Pleasant and Saginaw.

PRODUCTION AND VALUE OF SALT IN MICHIGAN AND UNITED STATES, 1860-1915.

Year.	U. S. production. Quantity, bbls.	Michigan production.		Per cent of total. Michigan.	Quantity.	Value. Michigan.	Michigan.	
		State Salt Inspectors.* Quantity, bbls.	U. S. G. S.† Quantity, bbls.				Rank Value.	Price, bbl.
1860	...	4,000	...	...	...	...	...	...
1861	...	125,000	...	...	...	...	...	...
1862	...	243,000	...	...	...	...	...	...
1863	...	466,000	...	...	...	...	...	...
1864	...	529,073	...	...	...	...	...	...
1865	...	477,200	...	...	...	...	...	...
1866	...	407,997	...	...	...	$734,395	...	$1.80
1867	...	474,721	...	...	...	840,255	...	1.77
1868	...	555,690	...	...	...	1,028,027	...	1.85
1869	...	561,288	...	...	...	786,835	...	1.58
1870	...	621,352	...	...	...	820,185	...	1.32
1871	...	728,175	...	...	...	1,063,135	...	1.46
1872	...	724,481	...	...	...	1,057,742	...	1.46
1873	...	821,346	...	...	...	1,127,984	...	1.37
1874	...	1,026,970	...	...	...	1,220,094	...	1.19
1875	...	1,081,856	...	...	...	1,190,042	...	1.10
1876	...	1,482,729	...	...	...	1,556,865	...	1.05
1877	...	1,660,997	...	...	...	1,411,847	...	0.85
1878	...	1,855,884	...	...	...	1,577,501	...	0.85
1879	...	2,058,040	...	...	...	2,099,200	...	1.02
1880	5,961,060	2,676,588	2,485,177	41.69	1	2,271,931	...	0.75
1881	6,200,000	2,750,299	...	44.35	1	2,418,171	...	0.85
1882	6,412,373	3,037,317	3,037,317	47.36	1	2,126,122	...	0.70
1883	6,192,231	2,894,672	2,894,672	46.74	1	2,344,684	...	0.81
1884	6,514,937	3,161,806	3,161,806	48.53	1	2,392,648	...	0.757
1885	7,038,653	3,297,403	3,297,403	46.84	1	2,967,663	...	0.900
1886	7,707,081	3,667,257	3,667,257	47.58	1	2,426,989	...	0.661
1887	8,003,962	3,944,309	3,944,309	49.17	1	2,291,842	...	0.581
1888	8,055,881	3,866,228	3,866,228	47.99	1	2,261,743	...	0.585
1889	8,005,565	3,846,979	3,856,929	48.17	1	2,088,909	...	0.541
1890	8,776,991	3,838,637	3,838,632	43.72	1	2,302,579	...	0.600
1891	9,987,945	3,927,671	3,966,748	39.52	1	2,037,289	...	0.513
1892	11,698,890	3,812,504	3,829,478	32.81	1	2,046,963	...	0.523
1893	11,897,208	3,514,485	3,057,898	25.70	2	888,837	...	0.287
1894	12,968,417	3,138,941	3,341,425	26.53	2	1,243,619	...	0.375
1895	13,669,649	3,529,362	3,343,395	24.46	2	1,048,251	...	0.315
1896	13,850,726	3,336,242	3,164,238	22.89	2	718,408	...	0.229
1897	15,973,202	3,622,764	3,993,225	24.99	2	1,243,619	...	0.313
1898	17,612,634	4,171,916	5,263,564	29.88	2	1,628,081	...	0.311
1899	19,708,614	4,732,669	7,117,382	36.14	2	2,205,924	...	0.309
1900	20,869,342	4,738,085	7,210,621	34.55	2	2,033,731	2	0.282
1901	20,566,661	5,580,101	7,729,641	37.58	1	2,437,677	1	0.328
1902	23,849,231	4,994,245	8,131,781	34.10	2	1,535,823	2	0.188
1903	18,968,089	4,387,982	4,297,542	22.65	2	1,119,984	2	0.260
1904	22,030,002	5,390,812	5,425,904	24.62	2	1,579,206	2	0.309
1905	25,966,122	5,671,253	9,492,173	35.24	1	1,851,332	2	0.196
1906	28,172,380	5,644,559	9,936,802	36.31	1	2,018,760	2	0.203
1907	29,704,128	6,298,463	10,786,630	35.39	1	2,231,129	2	0.208
1908	28,822,062	6,247,073	10,194,279	35.34	1	2,458,303	1	0.241
1909	30,107,646	6,055,661	9,966,744	33.10	1	2,732,556	1	0.274
1910	30,305,656	5,597,276	9,452,022	31.18	2	2,231,262	2	0.236
1911	31,183,968	...	10,320,074	33.10	2	2,633,155	1	0.255
1912	33,324,808	...	10,946,739	32.84	1	2,974,429	1	0.277
1913	34,393,227‡	...	11,528,800	33.52	1	3,293,032	1	0.285
1914	34,402,772	...	11,670,976	33.92	1	3,299,005	1	0.283
1915	...	...	12,588,788	...	1	4,304,731	1	0.342
Tot'l	...	...	221,806,600	...	...	$94,202,494	...	...

*Office of State Salt Inspector abolished in 1911.
†In cooperation with the Michigan Geological Survey after 1909.
‡Includes production of Porto Rico.

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PRODUCTION AND VALUE OF SALT IN MICHIGAN BY GRADES, 1906-1915.

Year.	Table and dairy.		Packers.			
			Common fine.		Common coarse.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Barrels.		Barrels.		Barrels.	
1906....	509,905	$362,368	2,927,478	$757,470	2,021,287	$618,727
1907....	657,509	392,641	3,601,270	914,154	1,743,840	471,378
1908....	584,452	620,647	3,454,062	968,617	2,020,956	610,286
1909....	585,370	732,907	3,530,303	1,125,095	2,103,719	647,878
1910....	798,434	565,653	2,216,181	734,828	1,992,465	596,301
1911....	817,486	742,702	2,362,075	698,203	2,070,745	745,720
1912....	905,593	920,782	2,225,337	645,692	2,086,492	835,673
1913....	1,028,000	1,037,402	2,704,936	852,135	2,259,164	896,521
1914....	1,092,344	1,025,164	2,668,989	911,016	2,380,378	870,715
1915....	1,233,117	1,420,382	3,096,644	1,181,337	2,265,352	1,001,167

Year.	Packers.		Other rock, etc.		Brine and other.*	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Barrels.		Barrels.		Barrels.	
1906....	91,098	$33,733	....	....	4,387,043	$246,462
1907....	119,459	48,455	....	....	4,664,552	235,729
1908....	134,726	53,669	....	....	3,991,083	205,084
1909....	93,357	3,983	....	....	3,648,395	185,051
1910....	92,426	43,942	....	....	4,104,934	211,317
1911....	105,401	45,421	576,595	$181,865	4,387,772	219,244
1912....	223,866	84,638	763,908	250,680	4,737,038	236,852
1913....	50,557	25,371	727,364	244,172	4,756,779	237,431
1914....	†	†	712,530	252,024	4,816,735	240,086
1915....	....	....	....	....	5,073,940	380,491

Year.	Total.	
	Quantity.	Value.
	Barrels.	
1906	9,936,802	$2,018,760
1907	10,786,630	2,062,357
1908	10,194,270	2,458,303
1909	9,966,744	2,732,556
1910	9,452,022	2,231,262
1911	10,320,074	2,633,155
1912	10,946,739	2,974,429
1913	11,528,800	3,293,032
1914	11,670,976	3,299,005
1915	12,588,788	4,304,731

*Brine only after 1910.
†See common fine and common coarse after 1913.

PRODUCTION AND VALUE OF SALT IN MICHIGAN BY COUNTIES IN 1915.

County.	Table and dairy.		Packers. Common fine.		Packers. Common coarse.	
	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.
Bay, Isabella, Mason, Midland	*	*	974,236	$362,185	734,763	$338,933
Manistee	....	....	382,763	124,486	589,986	258,824
Saginaw	*	*	394,809	184,473	9,210	4,438
St. Clair	956,117	$1,251,436	934,394	401,292	497,728	234,906
Wayne	237,597	138,581	410,442	108,901	433,665	164,066
Total, barrels	1,233,117	$1,420,382	3,096,644	$1,181,337	2,265,352	$1,001,167
Tons	172,636	....	433,530	....	317,149	....

County.	Other grades.		Rock salt.		Brine.	
	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.
Bay, Isabella, Mason, Midland	37,650	$10,824	....	....	*	*
Manistee	*	*	....	....	*	*
Saginaw	10,754	1,440	....	....	*	*
St. Clair	*	*	....	....	*	*
Wayne	22,428	8,309	*	*	*	*
Total, barrels	113,148	$32,806	*	*	5,073,940	$380,491
Tons	15,841	....	*	*	710,352	....

County.	Total. Barrels.	Total. Value.	Quantity, per cent.	Value, per cent.
Bay, Isabella, Mason, Midland	1,786,027	$742,247	12.18	11.78
Manistee	980,377	383,639	8.92	12.80
Saginaw	414,995	190,626	3.40	5.79
St. Clair	2,429,889	1,899,712	19.00	42.88
Wayne	6,977,500	1,088,507	56.50	26.75
Total, barrels	12,588,788	$4,304,731	....	....
Tons	1,762,430	....	....	....

*Included in total.

CEMENT.

Growth of Industry.

Less than 1,000,000 barrels of Portland cement were made in the United States in 1895, a little more than a fifth of the present production of Michigan. In 1895, the rotary kiln, using powdered coal as a fuel, was successfully introduced, and inaugurated the present era of concrete construction. Growth from 1895 to 1907 was phenomenal, the production in the latter year nearly reaching 48,000,000 barrels. The financial depression of 1907 caused a temporary check, but growth was resumed the following year and continued almost uninterruptedly up to 1913 when the maximum of 88,689,377 barrels were produced. Over production in 1913 followed by general business depression in 1914 caused decreases in production for 1914 and 1915, the total production being respectively 86,437,956 and 85,914,907 barrels.

A vertical kiln plant was erected near Kalamazoo, Michigan, as early as 1878 for manufacturing cement from marl and clay. The enterprise failed in 1892 because of the high cost of production. The Peerless Portland Cement Co., in 1896, erected a vertical kiln plant at Union City, Branch county, and began the successful manufacture of cement from marl and shale. By 1902, however, rotary kilns replaced the old vertical types. In 1897 the Bronson Portland Cement Co. erected a plant at Bronson, Branch county, and next year the Coldwater Portland Cement Co., now the Wolverine Portland Cement Co., built a plant at Coldwater and Quincy, also in Branch county.

The "boom" years of the Portland Cement industry in Michigan were between 1899 and 1901, twenty companies being organized in this period for the manufacture of cement from marl. Some companies made very elaborate plans but never got beyond that stage. Only ten reached the productive stage and but five are now in operation. Since 1896, thirty-four different cement plants have been projected or built in Michigan. Twelve are now in operation.

Raw Materials.

In Michigan, the principal raw materials for the manufacture of Portland cement are marl and limestone, and clay and shale. A small quantity of gypsum is also used. The early companies planned to use marl and clay or shale. Limestone has been substituted for marl by some of the companies on account of the great increase in kiln capacity secured through its use. Of eleven plants, seven are using marl and clay and four limestone and shale or clay.

The following table shows that Michigan produced 4,765,295 barrels

in 1915 as compared with 4,285,345 barrels in 1914, an increase of 479,949 barrels. Shipments increased from 4,218,429 barrels in 1914 to 4,727,768 barrels in 1915, a gain of 509,339 barrels. Both production and shipments were the largest in the history of the industry in Michigan. The value of cement sold in 1915 was $4,454,608, as against $4,064,781 in 1914, a gain of $389,827. The average price in 1915 was $0 942 per barrel or $0.022 per barrel lower than in 1914.

PRODUCTION, VALUE, ETC., OF PORTLAND CEMENT IN MICHIGAN AND UNITED STATES, 1896-1915.

Year.	No. of plants in operation.	Michigan Rank.	No. of kilns, Rotary.	Daily capacity. Bbls.	Michigan, Cement made. Bbls.	U. S., Cement made. Bbls.	Michigan, per cent made.	*Change per cent cement made.	Michigan, Cement shipped. Bbls.	Michigan, Cement shipped. Value.	U. S., Cement shipped. Value.	Michigan, per cent of value.	Michigan, stock on hand Dec. 31. Bbls.	Michigan, average price per barrel.	U. S., average price per barrel.
1896	1	....	....	....	4,000	1,543,023	0.25	....	....	$7,000	$2,424,011	0.29	....	$1.75	$1.57
1897	2	....	....	....	15,000	2,677,775	0.56	275.0	....	26,250	4,315,891	0.6	....	1.75	1.61
1898	2	....	....	....	77,000	3,692,284	2.11	413.3	....	134,750	5,970,773	2.3	....	1.747	1.62
1899	4	4	....	....	343,566	5,652,266	6.1	346.2	....	513,849	8,074,371	6.36	....	1.492	1.43
1900	6	2	....	....	664,750	8,482,020	7.8	93.4	....	830,990	9,280,525	8.9	....	1.25	1.09
1901	10	3	....	....	1,025,718	12,711,225	8.0	54.1	....	1,128,290	12,532,360	9.0	....	1.10	0.99
1902	10	3	....	....	1,577,006	17,230,644	9.1	53.7	....	2,134,396	20,864,078	10.2	....	1.353	1.21
1903	13	3	....	....	1,955,183	22,342,973	8.7	23.9	....	2,674,780	27,713,319	9.7	....	1.367	1.24
1904	16	4	....	....	2,247,160	26,505,881	8.5	14.9	....	2,365,656	23,355,119	10.1	....	1.052	0.88
1905	16	5	....	....	2,773,283	35,246,812	7.9	23.4	....	2,921,507	33,245,867	8.7	....	1.053	0.94
1906	14	4	....	....	3,747,525	46,463,424	8.06	35.5	....	4,814,965	52,466,186	9.2	....	1.284	1.13
1907	14	4	....	....	3,572,668	48,785,390	7.3	−4.6	....	4,384,731	53,992,551	8.1	....	1.227	1.11
1908	15	7	....	....	2,892,576	51,072,612	5.6	−19.0	....	2,556,215	43,547,679	5.8	....	0.883	0.85
1909	12	7	....	....	3,212,751	64,991,431	4.9	11.6	....	2,619,259	52,858,354	4.9	....	0.815	0.813
1910	12	8	....	....	3,687,719	76,549,951	4.8	11.7	....	3,378,940	68,205,800	4.9	....	0.916	0.891
1911	11	8	96	22,400	3,686,716	78,528,637	4.69	−0.03	3,651,094	3,024,676	66,248,817	4.56	506,758	0.82	0.843
1912	11	8	92	19,450	3,494,621	82,438,096	4.23	−5.21	4,081,281	3,145,001	69,109,800	4.55	370,956	0.861	0.813
1913	11	8	83	19,900	4,186,236	92,097,131	4.21	19.79	4,218,429	4,228,879	88,689,377	4.77	473,563	1.036	1.005
1914	11	7	77	19,100	4,285,345	88,230,170	4.85	2.37	4,727,768	4,064,781	86,437,956	4.70	538,846	0.964	0.927
1915	11	5	71	20,800	4,765,294	85,914,907	5.55	11.2		4,454,608	86,891,681	5.11	576,222	0.942	0.86

*Minus sign indicates decrease.

GYPSUM.

The annual production of gypsum in Michigan from 1868 to 1890 never reached 75,000 tons. The growth of the industry began in 1891, and the production reached 139,557 tons in 1892. The financial depression in the United States in 1892-3 caused a decrease in the production to only 66,519 tons in 1895. Growth was resumed the following year and in 1899 the production reached 144,776 tons. From 1899 to the present the growth has been almost uninterrupted. The maximum production of 423,896 tons was attained in 1913. The production decreased to 393,006 in 1914, and to 389,791 in 1915.

The growth of the industry is chiefly due to the invention of wall plaster, plaster board, fire-proofing, calcimines, and various cements, From 1869 to 1887, more than 50 per cent of the mine product was ground for land plaster. Since 1887, the grinding of land plaster has become relatively unimportant in comparison with the manufacture of other gypsum products. Land plaster formed but 2.5 per cent of the total production in 1915.

In 1915 there were 8 mines and 8 mills in operation. Seven mines and mills were located near Grand Rapids and one mine and mill at Alabaster, Arenac county.

Three gypsum beds are worked in Kent county. The two upper beds, respectively 6 and 12 feet in thickness, are near the surface. The first is quarried and the second is both quarried and mined. The third bed about 22 feet thick, is about 60 feet below the second, and is mined. At Alabaster, the gypsum bed is from 18 to 23 feet thick and is quarried on an extensive scale.

A higher bed has been discovered south of Alabaster in the vicinity of Turner, Twining, and the deserted village of Harmon City, Arenac county. It is from 50 to 100 feet above the Alabaster bed. This bed is known as the Turner bed and appears to be from 5 to 22 feet thick. Test holes north of Alabaster show the presence of a number of deeper gypsum beds from 5 to 25 feet in thickness. Thick gypsum beds are reported by well drillers at Ionia, Ionia county, and near Cass City, Tuscola county. Beds 6 to 12 feet in thickness were struck in shallow wells at Bellevue and Eaton Rapids, Eaton county. Gypsum was formerly quarried on the west side of St. Ignace peninsula.

Gypsum also occurs on the east side of the peninsula and on St. Martin's Island.

For a more complete report on the gypsum industry in Michigan, the reader is referred to Publication 19, (Geol. Ser. 16) Mineral Resources for 1914.

PRODUCTION OF GYPSUM IN MICHIGAN, 1868-1915.

Year.	Ground into land plaster. Tons.	Gypsum calcined into plaster. Tons.	Sold crude. Tons.	Total production. Tons.	Total value.	Rank.	
						Quantity.	Value.
Before 1868.	132,043	14,285	....	146,328	$671,022	....	....
1868........	28,837	6,244	....	35,081	165,298	....	....
1869........	29,996	7,355	....	37,351	178,824	....	....
1870........	31,437	8,246	....	39,683	191,718	....	....
1871........	41,126	8,694	....	49,820	234,054	....	....
1872........	43,536	10,673	....	54,209	259,524	....	....
1873........	44,972	14,724	....	59,696	297,678	....	....
1874........	39,126	14,723	....	53,849	274,284	....	....
1875........	27,019	10,914	....	37,933	195,386	....	....
1876........	39,131	11,498	....	50,629	248,504	....	....
1877........	40,000	9,819	....	49,819	238,550	....	....
1878........	40,000	8,634	....	48,634	229,070	....	....
1879........	43,658	9,070	....	52,728	247,192	....	....
1880........	49,570	18,929	....	68,499	349,710	....	....
1881........	33,178	20,145	....	53,323	293,872	....	....
1882........	37,821	24,136	....	61,957	344,374	....	....
1883........	40,082	28,410	....	68,492	377,567	....	....
1884........	27,888	27,959	....	55,847	335,382	....	....
1885........	28,184	25,281	....	53,465	286,802	....	....
1886........	29,373	27,370	....	56,748	308,094	....	....
1887........	28,794	30,376	....	59,170	329,392	....	....
1888........	22,177	35,125	....	57,302	347,531	....	....
1889........	19,823	36,800	....	56,623	353,869	....	....
1890........	12,714	47,163	15,000	74,877	192,099	....	....
1891........	15,100	53,600	11,000	97,700	223,725	....	....
1892........	14,458	77,599	47,500	139,557	306,527	....	....
1893........	16,263	77,327	31,000	124,590	303,921	....	....
1894........	11,982	47,976	20,000	79,958	189,620	....	....
1895........	9,003	51,028	6,488	66,519	174,007	....	....
1896........	6,582	60,352	700	67,634	146,424	....	....
1897........	7,193	71,680	16,001	94,874	193,576	....	....
1898........	13,345	77,852	1,984	93,181	204,310	....	....
1899........	17,196	88,315	39,266	144,776	283,537	....	....
1900........	10,354	86,972	33,328	129,654	285,119	2	2
1901........	9,808	129,256	46,086	185,150	267,243	1	1
1902........	13,022	158,320	68,885	240,227	459,621	1	1
1903........	18,409	198,119	52,565	269,093	700,912	1	1
1904........	18,294	185,422	34,669	238,385	541,197	1	1
1905........	20,285	203,313	24,284	247,882	634,434	1	2
1906........	30,220	208,715	27,517	341,716	753,878	1	2
1907........	15,500	197,666	36,543	317,261	681,351	3	3
1908........	11,414	192,403	40,324	327,810	491,928	1	3
1909........	11,890	344,171	45,781	394,907	1,213,347	2	1
1910........	7,097	240,905	64,566	357,174	667,199	2	2
1911........	15,548	206,299	79,050	347,296	523,926	3	4
1912........	10,103	243,656	63,819	384,297	621,547	2	3
1913........	9,604	278,368	60,706	423,896	721,325	3	3
1914........	9,322	249,648	61,227	393,006	705,841	3	3
1915........	9,799	245,484	69,572	389,791	686,309	....	....
Totals..	1,242,276	4,431,119	997,861	7,284,367	$18,931,620	....	....

PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1915.

Year.	Crude gypsum mined.	Gypsum sold crude.							
		To Portland cement mills.		As land plaster.		For other purposes.		Total sold crude.	
	Quantity.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	Tons.		Tons.		Tons.		Tons.	
1911	347,296	63,489	$69,497	15,548	$15,706	13	$52	79,050	$85,255
1912	384,297	53,711	52,420	10,103	9,375	5	50	63,819	61,845
1913	423,896	*	*	9,604	10,222	10,320	9,011	60,706	55,969
1914	393,006	*	*	9,322	10,761	....	....	61,227	51,242
1915	389,791	*	*	9,799	9,894	*	*	69,572	63,236

Year.	Gypsum sold calcined.									
	As mixed wall plaster.		As plaster of Paris, etc.		As stucco.		As dental plaster.		To plate glass works.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.		Tons.	
1911	146,920	$381,362	47,989	$88,168	....	....	20	$110	11,370	$19,031
1912	146,099	368,676	937	3,229	82,010	$168,734	3	12	6,214	8,078
1913	166,711	437,720	*	*	95,402	202,675	*	*	*	*
1914	163,972	475,638	*	*	83,780	173,172	*	*	....	....
1915	155,861	426,432	*	*	80,172	177,317	*	*	*	*

*Included in total.

PRODUCTION OF GYPSUM IN MICHIGAN, 1911-1915.—*Concluded.*

Year.	Gypsum sold calcined.				Total value.	Kettles in mill.		Daily capacity of mill.	Shifts run by mills during year.		No. mines and quarries.	No. mills.
	For other purposes.		Total sold calcined.									
	Quantity.	Value.	Quantity.	Value.		No.	Size.	24 hrs.	Total No.	Hrs. in shift.		
	Tons.		Tons.					Tons.				
1911	....	....	206,299	$488,671	$573,926	29	8 x 10	2,200+	....	....	8	8
1912	8,393	$10,973	243,656	559,702	621,547	28	8 x 10	2,140	1,850	11	6	8
1913	9,897	15,850	278,368	665,356	721,325	28	8 x 10	1,785	1,368	11	7	8
1914	1,811	5,433	249,648	654,599	705,841	28	8 x 10	1,860	2,043	11	8	8
1915	*	*	245,484	623,073	686,309	26	....	....	....	....	8	8

*Included in total.

CLAY.

The clays of Michigan are of three general classes, viz.: (1) morainic or drift clays (2) lake clays and (3) river silts. Deposits of kaolin or china clays are not known in Michigan and the chances for the occurrence of commercial deposits of such clays appear to be small. Deposits of kaolin have been reported at various places in the Northern Peninsula, but these as far as investigated, proved to be white or calcareous lake clays of the slip variety. The morainic clays—boulder and till clays, are always calcareous, some of them being very high in lime. The lake clays are generally less calcareous but locally, as in limestone areas, they may contain a large percentage of lime. The river silts are the least calcareous but they are usually gritty. On account of the high content of lime most of the clays burn white. In many beds, however, there is an upper portion relatively free from lime which burns red, and a lower one very high in lime which burns white or cream color. The absence of lime in the upper portion is due to leaching.

The morainic or drift clays contain pebbles, and boulders hence the name "boulder clay," and locally lime concretions. Screening and washing have been resorted to in some cases but the extra expense is generally prohibitive except in districts where good clays are wanting or where the clays possess exceptional burning qualities. The lake clays are comparatively free from pebbles and coarse sand but some contain much very fine grit. These clays are generally suitable for making common brick and tile. There are inexhaustible supplies of such clays in the eastern portion of the Southern Peninsula from Arenac county south to the Ohio boundary. Large areas of lake clays also occur in Chippewa and Ontonagon counties.

The morainic or boulder clays have been developed for the manufacture of common brick and tile at many places in the state but generally on a small scale. The lake clays in the vicinity of West Detroit have been developed very extensively for making common brick. Important developments have also been made near Paines and West Saginaw, Saginaw county, and at numerous places in Lenawee, Monroe, and Macomb counties.

In Ontonagon county some of the clays are of the slip variety and are suitable for glazing pottery. A deposit of slip clay is also reported near Harriette, Wexford county.

Most of the surface clays in Michigan are low grade and generally the mining of such clays is merely incidental to the manufacturing of common brick and tile. Nearly all of the clay sold as clay in Michigan is slip clay. It is mined chiefly near Rockland, Ontonagon county,

and shipped to potteries in Ohio and other states for glazing. The great distance of the beds from the centers of the pottery industry is an effective obstacle in retarding development. In some years a small amount of clay is sold for medicinal purposes.

PRODUCTION OF CLAY IN MICHIGAN, 1910-1915.

Year.	Slip clay.		Brick clay.		Miscellaneous clay.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.		Tons.		Tons.		Tons.	
1910...	1,363	$3,889	60	$105	1	$400	1,424	$4,394
1911...	1,744	5,090	18	32	2	150	1,764	5,272
1912...	2,034	6,164	....	....	9	9	2,043	6,173
1913...	1,710	6,504	....	....	....	....	1,710	6,504
1914...	1,463	4,572	....	....	....	....	1,463	4,572
1915...	1,198	3,805	*	*	*	*	3,142	5,605
Total...	....	....	....	....	....	....	11,546	$32,520

*Included in total.

POTTERY.

From 1899 to 1904, the development of the pottery industry in Michigan was erratic, the total value increasing from $29,741 in 1899 to $83,098 in 1902 and then decreasing to only $40,621 in 1904. Since then the industry has made a substantial growth every year and the value in 1915 was the largest in the history of the industry. In 1909, the total value was $95,439 and in 1915, $521,989, or over five times that of 1909. The largest gain was made in 1915, the value increasing from $265,194 to $521,989, a gain of 96.7 per cent.

The products are chiefly flower pots, white ware, and porcelain electrical supplies. Of six firms, three, the Detroit Flower Pot Co., Anton Hupprich of Detroit, and the Ionia Pottery Co., manufacture flower pots almost exclusively. The Jeffery-DeWitt Co., of Detroit, manufactures various porcelain products—sanitary ware, insulators, tumbling jars, crucibles, etc. The Mount Clemens Pottery Co., Macomb county, manufactures decorated ware.

The clays used for the manufacture of flower pots are obtained from Michigan but those used for porcelain electrical supplies and white ware are imported from other states or countries.

VALUE OF POTTERY PRODUCTS IN MICHIGAN, 1899-1915.

Year.	Rank of state.	No. firms.	Red earthenware, value.	Porcelain electrical supplies, value.	C. C. ware, value.	Miscellaneous, value.	Total value.	Gain per cent.	Per cent. of total product in U. S.
1899	18	4	$29,641	....	$100	....	$29,741	....	.17
1900	17	4	34,317	....	....	....	34,317	15.4	.17
1901	16	5	42,465	....	....	$2,400	44,865	30.2	.20
1902	14	4	44,098	....	....	39,000	83,098	87.4	.41
1903	19	4	42,007	....	....	6,000	48,007	−42.2	.19
1904	17	4	40,621	....	....	3,000	43,621	−9.1	.17
1905	17	5	*	....	*	7,000	45,961	4.5	.16
1906	17	6	43,510	....	....	7,600	51,110	11.2	.16
1907	16	6	54,474	....	....	7,100	61,574	18.5	.20
1908	16	6	54,659	....	....	7,750	62,409	1.5	.25
1909	13	5	60,939	....	....	34,500	95,439	52.9	.31
1910	13	6	90,450	*	....	13,300	112,697	18.1	.33
1911	13	6	80,580	*	*	*	130,490	15.8	.38
1912	10	6	99,555	*	....	*	194,892	49.3	.53
1913	10	5	65,000	*	....	*	222,133	20.8	.59
1914	9	5	106,452	*	*	*	265,194	33.0	.75
1915	8	6	112,863	*	*	*	521,989	96.7	1.40
Totals	....	....	....	....	....	....	$2,047,537	....	....

*Included in the total.

BRICK AND TILE PRODUCTS.

Raw materials. Most of the surface clays (see Clay) in Michigan are of low grade and of three general classes, (1) morainic or drift clays, (2) lake clays, and (3) river silts. The morainic clays are usually calcareous, generally containing from 10 to 15 per cent of lime. They also contain sand, pebbles and boulders, hence the name boulder clay. Due to their sandy or calcareous nature, most of the clays are adapted for making common brick and tile or low grade pottery. The high lime content causes most of the clays to burn white or cream colored. In some places, leaching has removed the lime to the depth of a few feet and clay from this surface portion burns red.

Exposures of clay or shale beds suitable for the manufacture of fire, vitrified and front brick, vitrified tile, fire-proofing and other higher grade products are not abundant. Near Rockland, Ontonagon county, some of the lake clays belong to the slip varieties and are used for glazing pottery. At Grand Ledge, Jackson, Corunna, near Bay City and Flushing, shales belonging to the coal measures have been utilized for vitrified and front brick, vitrified tile, sewer pipe, conduits, fire-proofing, etc. A project for the manufacture of front brick from Coal Measure shales is now under way at Williamston. The Baker Clay Products Co., at Grand Ledge have a modern plant equipped with continuous kilns and have begun the manufacture of front brick.

Production. In 1915, the value of brick and tile products in Michigan was $2,248,068, exclusive of pottery, as compared with $2,434,872 in 1914. This represents a decrease of $186,804 or 7.6 per cent. The quantity of common brick increased from 269,154,000 in 1914 to 277,399,000 in 1915, a gain of 3.7 per cent. The value however, decreased from $1,633,216 in 1914 to $1,461,188, a loss of $172,028 or 10.5 per cent. The average price of common brick in 1915 was only $5.23 as against $6.07 in 1914. The value of drain tile decreased from $421,941 in 1914 to $305,156, a loss of $126,785 or 30 per cent. The cause of the decreases in many of the smaller plants was the abnormally wet season, which prevented operation.

The manufacture of common brick has made great development in the vicinity of Detroit where extensive beds of suitable lake clays occur.

In 1915, of a total of 277,399,000 common brick, 225,015,000 were made in Wayne county. Drain tile is next to common brick in importance with a reported value of $305,156. Sewer pipe is manufactured on a large scale at Grand Ledge and Jackson, but there are only two producers, hence no figures of production and value are given. Grand Ledge is also the chief center in the state for the pro-

duction of drain tile. The manufacture of front brick in Michigan is in its infancy but with one new plant in operation at Grand Ledge and another being promoted at Williamston, the industry bids fair to become an important one. This will meet a great need in the state, since large quantities of front brick are annually imported from bordering states.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1915.

Year.	Common brick.		Average price per M.	Front brick.		Average price per M.	Vitrified brick.		Average price per M.	Fire brick.		Average price. per M.
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
1899	200,144,000	$933,176	$4 66	4,290,000	$58,920	$13 73	*	*	....	....	....	....
1900	180,892,000	863,250	4 77	8,421,000	48,411	5 75	*	*	$12 42	....	....	....
1901	215,836,000	1,095,254	5 07	9,476,000	64,031	6 76	*	*	12 30	....	....	....
1902	237,254,000	1,331,752	5 61	5,684,000	42,792	7 53	*	*	12 26	....	....	....
1903	215,791,000	1,251,572	5 80	2,225,000	19,000	8 54	*	*	13 27	....	....	....
1904	205,196,000	1,116,714	5 44	1,080,000	7,500	6 94	*	*	13 28	....	....	$13 00
1905	211,558,000	1,152,505	5 45	693,000	5,995	8 65	6,112,000	$81,706	13 37	....	....	19 37
1906	206,583,000	1,178,202	5 70	1,474,000	14,162	9 61	6,229,000	81,814	13 13	....	....	10 05
1907	200,817,000	1,181,015	5 88	3,956,000	32,116	8 12	7,911,000	94,601	11 96	....	....	12 00
1908	181,049,000	994,525	5 49	1,896,000	19,496	10 28	6,165,000	76,630	12 43	....	....	....
1909	219,820,000	1,250,787	5 69	2,379,000	18,654	7 84	10,473,000	129,283	12 34	....	....	....
1910	232,551,000	1,363,316	5 86	2,209,000	27,533	12 46	9,080,000	116,446	12 82	....	....	....
1911	252,465,000	1,301,998	5 16	2,498,000	31,572	12 64	5,597,000	78,336	14 00	....	....	18 08
1912	271,189,000	1,592,283	5 87	3,934,000	41,476	10 54	6,600,000	92,000	13 94	*	*	17 78
1913	273,571,000	1,626,287	5 94	505,000	5,941	11 76	8,571,000	126,062	14 71	*	*	16 41
1914	269,154,000	1,633,216	6 07	1,488,000	21,121	14 19	7,733,000	120,562	15 59	*	*	19 78
1915	277,399,000	1,461,188	5 23	*	*	11 28	*	*	14 50	*	*	....
Totals	3,851,269,000	....	....	....	....	....	....	....	....	....	....	....

*Concealed; less than three producers.

ANNUAL PRODUCTION OF BRICK AND TILE PRODUCTS IN MICHIGAN, 1899-1915.—*Concluded.*

Year.	Stove linings.	Drain tile.	Sewer pipe.	Fire-proofing.	Tile (not drain.)	Miscellaneous.	Hollow building tile or blocks.	Per cent of total product in U. S.	Rank of state.	No. of firms operating.	Total value.
	Value.	Value.	Value.	Value.	Value.	Value.	Value.				
1899	...	$140,171	$50,300	$5,900	...	$22,709	...	1.68	13	196	$1,254,256
1900	...	114,747	57,916	2,350	...	406	...	1.50	17	189	1,147,378
1901	...	98,972	*	1,880	...	637	...	1.71	14	180	1,497,169
1902	...	96,645	*	3,290	...	...	...	1.69	13	182	1,660,942
1903	...	129,028	*	...	...	...	$19,138	1.58	14	178	1,662,414
1904	...	208,088	*	...	...	...	8,080	1.58	14	168	1,670,892
1905	...	205,445	*	*	...	...	3,585	1.41	16	154	1,719,746
1906	...	314,098	*	...	...	...	4,290	1.38	16	142	1,793,367
1907	...	289,868	*	...	...	1,500	6,386	1.39	17	136	1,786,190
1908	...	327,630	*	4,100	...	40,100	...	1.54	16	132	1,666,381
1909	...	364,006	*	*	...	66,128	...	1.44	16	122	1,947,059
1910	...	348,205	*	...	...	*	...	1.53	15	118	2,083,525
1911	$3,971	313,072	*	*	*	228,530	*	1.53	15	111	1,953,442
1912	*	387,945	*	1,461	*	235,459	*	1.73	13	101	2,350,606
1913	...	415,543	*	*	*	350,000	*	1.73	13	95	2,451,242
1914	*	421,941	*	3,752	*	234,280	*	1.88	10	90	2,434,872
1915	...	305,156	*	10,850	*	49,755	*	...	...	82	2,248,068
Totals	...	$4,480,560	...	...	...	...	...	...	...	...	$31,327,549

*Concealed under miscellaneous; less than three producers.

ANNUAL PRODUCTION AND VALUE OF SAND-LIME BRICK IN MICHIGAN AND UNITED STATES, 1904-1915.

Year.	No. of operating firms reporting.—Mich.	No. of operating firms reporting.—U. S.	Michigan production.								Total value Michigan.	Change per cent.—Michigan.	Total value United States.	Per cent of total production of U. S.	Rank.	
			Common brick.		Average price per thousand.	Front brick.		Average price per thousand.	Fancy brick.							
			Quantity, (thousands).	Value.		Quantity, (thousands).	Value.		Quantity, (thousands).	Value.					Production.	Value.
1904...	10	57	9,886	$64,034	$6 64	580	$5,234	$9 02	19	$497	$69,765	....	$463,128	15.6	1	1
1905...	12	84	21,841	155,883	6 28	1,577	12,893	8 17	24	526	169,302	142.7	972,064	17.4	1	1
1906...	11	87	27,281	162,879	5 97	1,796	12,022	6 69	7	20	174,921	3.3	1,170,005	15.0	1	2
1907...	13	94	25,488	158,606	6 22	*2,000	14,234	7 17	......	......	172,840	−1.2	1,225,769	14.1	1	1
1908...	10	87	21,997	131,827	5 99	*900	6,982	7 76	......	......	138,809	−19.7	1,029,699	13.5	1	1
1909...	11	74	34,217	207,082	6 05	*1,600	11,144	6 97	......	......	218,226	57.2	1,150,580	19.0	1	1
1910...	10	76	37,648	218,627	5 81	*3,256	22,022	6 76	......	......	240,649	10.3	1,169,153	20.5	1	1
1911...	10	66	32,889	192,224	5 84	2,726	17,777	6 52	......	......	210,001	−12.7	897,664	23.4	1	1
1912...	11	71	48,129	307,106	6 38	1,163	9,626	8 27	......	......	316,732	50.8	1,200,223	26.4	1	1
1913...	12	68	49,373	315,882	6 40	†	†	......	†	†	321,245	1.7	1,238,325	25.9	1	1
1914...	12	62	41,456	248,113	5 98	†	†	......	†	†	255,784	−24.4	1,058,512	23.5	1	1
1915...	11	....	46,513	281,009	6 04	†	†	......	†	†	286,948	+11.8	1,135,104	25.3	1	1
Total..	....	....	399,718	$2,443,272	$6 11	....	....	.....	......	......	$2,575,222	....	....	....	......	......

*Estimated. †Included in total.

SAND LIME BRICK.

The growth of the sand lime brick industry has been in the average output of the plants rather than in the number of plants. In 1904 ten plants were in operation and in 1915, eleven. In 1904, ten plants produced 9,886,000 common brick and in 1915, eleven plants produced 46,513,000 or over 4½ times as many. The average price of common brick in 1904 was $6.64 per thousand, but in 1910 it had fallen to only $5.81 per thousand. The price in 1915 was $6.04 per thousand.

MINERAL AND SPRING WATERS.

The amount and value of mineral and spring waters produced in Michigan fluctuate greatly from year to year. The principal factors affecting the production are (1) general business conditions, (2) local conditions affecting municipal supplies. The largest decreases in production in Michigan occurred in the general business depression of 1906 and 1907 and of 1914. The municipal water supplies in certain cities are unsafe or unpalatable, and consequently a thriving business of vending spring waters has grown up in these cities. During the past three or four years, the quality of the supplies has been greatly improved through the installation of filtration plants or the development of new sources.

A general though intermittent decrease in the production of mineral and spring waters in Michigan has occurred since 1902, the production falling from 8,653,690 gallons in that year to only 884,893 gallons in 1913. The production in 1914 and 1915 was respectively 931,343 gallons and 913,765 gallons.

PRODUCTION AND VALUE OF MINERAL WATERS IN MICHIGAN, 1900-1915.

Year.	Rank.		No. of Springs active.	Total.		Medicinal. Value.	Table. Value.	Average price per gal.
	Quantity.	Value.		Quantity. Gals.	Value.			
1900	6	4	28	3,398,996	$411,935			$0.121
1901	2	1	28	7,019,168	1,195,614			0.170
1902	1	9	28	8,653,690	275,763			0.032
1903	1	9	19	6,919,107	200,668			0.029
1904	7	13	19	3,385,675	118,422			0.035
1905	4	4	17	2,684,800	277,188	$38,900	$238,288	0.100
1906	13	23	19	902,528	73,357			0.081
1907	8	15	19	1,472,679	127,133	35,091	92,042	0.086
1908	8	16	24	2,004,433	88,910	5,995	82,915	0.044
1909	5	16	19	2,760,604	104,454	6,099	98,355	0.035
1910	9	17	17	1,454,020	69,538	100	69,438	0.048
1911	11	24	23	1,713,401	72,253	12,156	60,097	0.042
1912	12	19	17	1,420,465	75,611	777	74,834	0.053
1913	17	24	20	884,893	52,642	3,605	49,037	0.059
1914	16	20	22	931,343	70,310	12,252	58,058	0.075
*1915			18	913,765	72,711	5,165	67,546	0.080
Total				46,519,567	$3,286,509	$114,140	$890,610	$0.071

*Figures subject to revision.

NATURAL GAS.

Michigan produces very little natural gas, and most of this is produced in the southeastern part of the state in Macomb, Oakland, and St. Clair counties. Gas also occurs in Manistee county. In Oakland and Manistee counties the supply is obtained from the surface deposits. The gas usually occurs in small volume and under low pressure. The source of the gas is presumably the bituminous and petroliferous Devonian formations which underlie these counties. The wells are usually sufficient only for a family or two and usually last for a number of years. Some wells "play out" in a few weeks, others last for many years. In Oakland and Macomb counties 25 or 30 of such wells are utilized by farmers for heating and lighting. According to reports the gas wells in the vicinity of Warren and Royal Oak in these counties have been declining rapidly in volume and pressure during the past two years.

There are many artesian wells around Portage Lake, Manistee county, which yield considerable gas. In 1913, a gas well was struck near Onekama on the north side of the lake. It yielded a large volume of gas under a pressure of nearly 190 pounds per square inch. Some of the other wells yield sufficient quantities of gas for heating and lighting one or more dwellings.

In the Port Huron oil field, oil is obtained from the Dundee limestone at depths varying from about 500 to 710 feet and many of the wells yield gas along with the oil. The wells of the G. B. Stock Xylite Grease & Oil Co. yield gas more than sufficient for pumping the wells. A number of the wells of the Michigan Central Oil & Gas Co. are reported to yield from 20,000 to 40,000 cubic feet of gas per day under pressures varying from 125 to over 250 pounds per square inch. A project was under way for utilizing the gas in lighting a small suburb of Port Huron. A number of other wells in and about the city bored for oil or water also yield more or less gas, which has been utilized for domestic and industrial purposes.

At Mt. Clemens, some of the mineral wells yield gas nearly sufficient for heating the boilers used in pumping.

The following table shows the production of natural gas for the past five years:

PRODUCTION OF NATURAL GAS IN MICHIGAN, 1911-1915.

Year.	No. of producers.	Domestic.		Industrial.		Other.		Total.	
		Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
		M. cu. ft.		M. cu. ft.		M. cu. ft.		M. cu. ft.	
1911...	22	930	$930	....	....	800	$400	1,730	$1,330
1912...	17	....	1,020	900	$450	....	....	900	1,470
1913...	....	....	....	....	....	....	....	1,805	1,405
1914...	....	....	....	....	....	....	....	2,442	1,442
1915...	16	960	960	....	....	1,100	550	2,060	1,510
Total..	....	....	....	....	....	....	....	8,937	$7,357

PETROLEUM.

Oil has been found in small quantities at many places in Michigan, notably at Port Huron, Allegan, and Saginaw. At Port Huron there are about thirty productive wells, but they are very small, the average yield being about one half barrel per day. The depth to the oil horizon in the vicinity of Port Huron is from about 500 to 650 feet. All of the wells yield gas which is utilized in operating the wells. A part of the oil is used by G. B. Stock Xylite Grease and Oil Co. in the manufacture of lubricants. The oil horizon at Allegan is about 1,300 feet in depth and at Saginaw 2,300 to 3,000 feet. The flows of oil were similar in quantity to those obtained at Port Huron but the greater depth made operation impracticable. There are but two producers of oil, hence figures of production are not given.

The reader is referred to Publication 14 (Geol. Ser. 11), Occurrence of Oil and Gas in Michigan. Publication 19, (Geol. Ser. 16) Mineral resources of Michigan for 1914, contains a history of the developments in the Port Huron oil field up to 1915.

TRAP ROCK.

There are inexhaustible resources of trap rock in the western half of the Northern Peninsula, chiefly in the iron and copper bearing districts. Trap rock is quarried at Marquette and Negaunee, Marquette county. Large quantities of amygdaloidal trap is produced incidentally in copper mining. The trap rock from Marquette county is harder, tougher, and less altered than that from the copper mines. The inferior wearing qualities of the amygdaloidal trap however is partially compensated by superior cementing power.

Most of the quarry product is crushed for road material and con-

crete. In some years a small amount is sold for rip rap. The great distance from markets is a serious obstacle to the development of the trap rock resources of the state.

PRODUCTION AND VALUE OF TRAP ROCK IN MICHIGAN, 1911-1915.

Year.	No. of producers.	Crushed stone.				Riprap. Rubble. Value.	Total. Value.	Rank. Value.
		Road making.		Concrete.				
		Quantity.	Value.	Quantity.	Value.			
		Tons.		Tons.				
1911...	3	....	....	45,250	$38,429	....	$51,000	8
1912...	5	21,805	$18,366	11,355	9,340	$8,500	36,206	8
1913...	5	24,920	23,369	*	*	*	92,201	10
1914...	5	25,690	24,863	4,448	4,771	....	34,406	12
1915...	6	28,262	29,764	18,775	22,047	*	105,855	....
Total...	....	100,677	$96,362	....	....	....	$319,368	....

*Included in total.

SHALE.

Shale is quarried in Michigan for use in making Portland cement and vitrified and front brick, sewer pipe, conduit and vitrified tile. It is quarried for Portland cement near Coldwater, at Paxton, Alpena county, and in Charlevoix county, and for the manufacture of ceramic products at Grand Ledge, (Eaton county), Jackson, Corunna (Shiawassee county), and Flushing, (Genesee county). A project is now under way for the development of shale beds at Williamston for the manufacture of front brick.

Excellent exposures of Coldwater shale occur at Richmondville, Sanilac county, and along the shore of Lake Huron from Forestville to White Rock in Sanilac and Huron counties. Numerous exposures also occur near Coldwater, Union City, Quincy, and Bronson, Branch county. A number of exposures of Antrim black shale occur in Charlevoix, Cheboygan and Alpena counties. Exposures of the blue Bell shale of the Traverse formation occur near Rockport, Alpena county and near Bell, Presque Isle county.

GRAPHITE.

Graphitic slate is quarried about 9 miles from L'Anse, Baraga county, by the Northern Graphite Works and the Detroit Graphite Company of Detroit. The graphitic material is ground for paint. The mines have not been operated during the past three years.

QUARTZ.

Vein quartz is mined near Ishpeming by the Michigan Quartz Silica Co. of Milwaukee and ground chiefly for wood filler and paint. Some of the product is used in making polishes. The quartz rock is practically pure silica. The mills are located at Ishpeming, Michigan, and at Milwaukee, Wisconsin. There is but one producer hence figures of production are not given.

MINERAL PAINTS.

Certain iron ores are mined in Iron county by Pickands Mather Co. of Cleveland, Ohio, for the manufacture of paint. The Acme White Lead & Color Co. of Detroit, manufactures a large amount and a variety of mineral paints. These are the only producers of mineral paints, hence figures of production and value cannot be given.

SUMMARY TABLE OF THE PRODUCTION AND VALUE OF

Mineral Products.	1911.		1912.	
	Quantity.	Value.	Quantity.	Value.
Brick and tile products, number of brick	260,560,000	$1,953,442	281,741,000	$2,350,606
Brick, sand-lime, number of brick	35,615,000	210,001	49,292,000	316,732
Bromine	(a)	(a)	(a)	(a)
Calcium chloride	(a)	(a)	(a)	(a)
Cement, Portland; bbls. made, value cement shipped	3,686,716	3,024,676	3,651,094	3,145,001
Clay, tons	2,202	5,437	2,043	6,173
Coal, tons	1,476,074	2,791,461	1,206,230	2,399,451
Copper, lbs	218,185,836	27,273,155	218,138,408	35,992,837
Graphite	....	(a)	....	(a)
Grindstones, tons	....	(a)	....	(a)
Gypsum and gypsum products, tons mined	347,296	573,926	384,297	621,547
*Iron ore, long tons	8,944,393	23,808,935	12,649,296	29,003,163
Iron, pig; long tons made; value pig iron shipped	304,654	(b)4,672,799	459,975	(b)6,579,048
Lime, tons made	80,709	352,608	74,720	311,448
Limestone	....	1,001,535	....	1,139,560
Mineral paints	....	(a)	....	(a)
Mineral and spring waters, gallons sold	1,713,401	72,253	1,420,465	75,611
Natural gas, M. cu. ft	....	1,330	900	1,470
Petroleum	....	(a)	....	(a)
Pottery	....	130,490	....	194,892
Precious stones	....	....	....	....
Quartz	....	(a)	....	(a)
†Salt, bbls	10,320,074	2,633,155	10,946,739	2,974,429
Sand and gravel, tons	2,185,165	565,969	2,681,821	818,603
Sandstone	....	12,985	....	16,438
Silver, fine oz. Troy	507,700	274,100	528,453	324,999
Trap rock	....	51,000	....	36,206
Miscellaneous	....	161,030	....	522,141
Total	....	$65,077,232	....	$79,931,757

*Figures from Iron Trade Review.
†Exclusive of bromine and calcium chloride.
(a) Included under miscellaneous.
(b) Excluded from total, covered by iron ore.
(c) Estimated.
(d) Copper sales.

MINERAL PRODUCTS IN MICHIGAN, 1911-1915.

1913.		1914.		1915.	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
282,664,000	$2,451,242	278,384,000	$2,434,872	281,819,000	$2,248,068
50,065,000	321,245	42,465,000	255,784	47,285,000	286,948
(a)	(a)	(a)	(a)	600,325	494,271
(a)	(a)	(a)	(a)	10,558	74,670
4,081,281	4,228,879	4,218,429	4,064,781	4,765,294	4,454,608
1,710	6,504	1,463	4,572	3,142	5,605
1,231,786	2,455,227	1,231,786	2,455,227	1,069,798	(c) 2,139,596
183,853,409	28,442,806	158,009,748	21,426,122	238,956,410	(d) 41,775,296
....	....	....	....	....	(a)
....	(a)	....	(a)	....	(a)
423,896	721,325	393,006	705,841	389,791	686,309
12,677,466	31,947,214	8,835,274	18,965,058	13,151,612	26,574,168
447,188	(b)6,568,920	379,619	(b) 5,229,948	(b) 486,106	6,624,559
77,088	331,852	66,507	287,648	81,359	349,979
....	1,408,708	....	1,457,961	....	1,828,766
....	(a)	....	(a)	....	(a)
884,893	52,642	931,343	70,310	913,765	72,711
1,805	1,405	2,442	1,442	2,060	1,510
....	(a)	....	(a)	....	(a)
....	222,883	....	265,194	....	521,989
....	....	....	(a)	....	(a)
....	(a)	....	(a)	....	(a)
11,528,800	3,293,032	11,670,976	3,299,805	12,588,788	4,304,731
6,424,168	1,529,142	3,647,790	1,118,978	3,776,726	1,036,739
....	19,224	....	(a)	....	(a)
295,173	178,284	413,500	228,665	585,933	297,068
....	92,201	....	34,406	....	105,855
....	540,626	....	565,147	....	119,905
....	$77,860,192	....	$57,641,013	....	$94,003,349

APPENDIX.

DIRECTORY OF THE PRODUCERS OF NON-METALLIC MINERALS IN MICHIGAN, 1915.

BRICK AND TILE MANUFACTURERS, 1915.

Operators.	Office.	Works.
Allegan County:		
Allegan Brick Works	Allegan	Allegan.
Zeeland Brick Co	Zeeland	Zeeland.
Barry County:		
Leonard, Wm	Delton	Delton.
Bay County:		
Michigan Vitrified Brick Co	Bay City	Bay City.
Berrien County:		
Mamer Brick Co	Benton Harbor	Benton Harbor.
Branch County:		
Reynolds & Son, Lorenzo D	Quincy	Algansee.
Charlevoix County:		
Boyne City Brick Co	Boyne City	Boyne City.
East Jordan Clay Products Co	East Jordan	East Jordan.
Northern Brick Co	Boyne Falls	Boyne Falls.
Chippewa County:		
Rudyard Brick Works	Rudyard	Rudyard.
Dickinson County:		
Vulcan Brick Works	Vulcan	Vulcan.
Eaton County:		
American Sewer Pipe Co	Broad St., Akron, Ohio	Grand Ledge.
Baker Clay Co	Grand Ledge	Grand Ledge.
Grand Ledge Clay Products Co	Grand Ledge	Grand Ledge.
Emmet County:		
De Arment, C. A	Petoskey	Petoskey.
Genesee County:		
Gale Bros	Atlas	Atlas.
Oliff, Thomas	Clio	Clio.
Duffield Brick & Tile Works	Duffield	Duffield.
McCann, Fred'k W	Gaines	Gaines.
Sharp, Frank	R. D. No. 1, Linden	South Mundy.
Flint Clay Products Co	Flint	....
Gladwin County:		
Korkoske, Christ	Gladwin	Gladwin.
Grand Traverse County:		
Traverse City Brick Co	Traverse City	Keystone.
Gratiot County:		
Ashley Tile Co	Ashley	Ashley.
Stevenson & Sons, David	Ashley	Ashley.
Ithaca Brick & Tile Yards	Ithaca	Ithaca.
Lee, Chas	North Star	North Star.
Peet, C. D	North Star	North Star.
Lyle G. Smith & Fred Bernard	St. Louis	St. Louis.
Riverside Brick & Tile Co	Sumner	Sumner.
St. Louis Tile Co	St. Louis	St. Louis.
Hillsdale County:		
Jerome Brick & Tile Co	Jerome	Jerome.
Gish & Connor	Waldron	Waldron.
Ingham County:		
Clippert, Spaulding & Co	Lansing	Lansing.
Ionia County:		
Brown, Albert	Saranac	Saranac.
Van Der Heyden, Fred H	Ionia	Ionia.

BRICK AND TILE MANUFACTURERS, 1915.—*Continued.*

Operators.	Office.	Works.
Isabella County:		
Kane Bros	Mt. Pleasant	Mt. Pleasant.
Jackson County:		
Simpson, Nathan F., Warden Michigan State Prison	Jackson	Jackson.
American Sewer Pipe Co	Akron, Ohio	Jackson.
Kalamazoo County:		
Zeeland Brick Co	Zeeland	Brownell.
Kent County:		
Grand Rapids Brick Co	Mich. Ave. and Fuller St., Grand Rapids	Grand Rapids.
Sparta Clay Works	Sparta	Sparta.
Lenawee County:		
Laurenson & Saunders	Addison	Addison.
Wilt, C. H	Blissfield	Blissfield.
Britton Pressed Brick Co	Ann Arbor	Britton.
Atkin, Wm. T	Deerfield	Deerfield.
Woodford & Son, B. F	Jasper	Jasper.
Ellis, G. D	Macon	Macon.
American Brick & Tile Co	Morenci	Morenci.
Comfort, Albert A	R. D., Tecumseh	Tecumseh.
Macomb County:		
Hartsig, Jacob	Warren	Centerline.
Hacker, Frank G	Mt. Clemens	Clinton.
Gass, East	R. D. No. 2, Washington	Davis.
Mt. Clemens Brick & Tile Co	Mt. Clemens	Mt. Clemens.
Warren Brick & Tile Works	Warren	Warren.
New Baltimore Brick & Tile Co	New Baltimore	New Baltimore.
Manistee County:		
Kujawske, Joseph	Oakhill	Oakhill.
Mecosta County:		
Nehmer, Wm. F	Big Rapids	Big Rapids.
Midland County:		
Rilett & Herwig, J. W	R. D. No. 3, Coleman	Coleman.
Midland Tile Works	Midland	Midland.
Monroe County:		
Meyer Bros	Azalia	Azalia.
Linenfelser Brick & Tile Co	Maybee	Maybee.
Angerer Clay Products Co	Scofield	Scofield.
Strong & Son, John	South Rockwood	South Rockwood.
Muskegon County:		
Holton Brick Co	Muskegon	Holton.
Newaygo County:		
Stevens & Sons, Wm	R. D., Grant	Grant.
Ottawa County:		
Zeeland Brick Co	Zeeland	Zeeland.
Saginaw County:		
Parker-Lohmann Brick & Tile Co	R. D. No. 10, Saginaw, W. S.	Saginaw, W. S.
Sperry Bros	Paines	Paines.
Day, James	R. D. No. 8, Saginaw	Saginaw.
Day, Thomas	R. D. No. 3, Saginaw	Saginaw.
Saginaw Paving Brick Co	1850 S. Jefferson Ave., Saginaw	Saginaw.
St. Clair County:		
Belknap & Phillips	Bell River Road, St. Clair	St. Clair.
Sanilac County:		
Croswell Brick Co	Croswell	Croswell.
Sandusky Brick & Tile Co	Sandusky	Sandusky.

BRICK AND TILE MANUFACTURERS, 1915.—*Concluded.*

Operators.	Office.	Works.
Shiawassee County:		
Detroit Vitrified Brick Co	Box 289, Corunna	Corunna.
Tuscola County:		
Thompson & Son, John	Tuscola	Tuscola.
Hall, Chas	Cass City	Cass City
Wayne County:		
Daniel & Bro. Brick Co., Jacob	291 Clippert Ave., Detroit	Detroit.
Haggerty, John S	1815 Dime Sav. Bk. Bldg., Detroit	Detroit.
Lonyo, Harsha Brick Co	644 Humboldt Ave., Detroit	Detroit.
McDonald & Son, John C	707 Hammond Bldg., Detroit	Springwells
Ajax Brick Co	66 Buhl Block, Detroit	Detroit.
Bunte Bros. Tile Co	Flat Rock	Flat Rock.
Clippert & Bro. Brick Co., Geo. H	1960 Michigan Ave., Detroit	Springwells.
Clippert, Wm	1960 Michigan Ave., Detroit	Springwells.
Detroit Roofing Tile Co	308 Hammond Bldg., Detroit	Springwells.
Mercier, Bryan, Larkins Brick Co	Michigan Ave. and Lonyo Road, Detroit	Springwells.
Lonyo Bros	613 Campbell Ave., Detroit	Springwells.
Porath Bros	306 Free Press Bldg., Detroit	Springwells.
Sass Bros. & Stuve	463 Lumley Ave., Detroit	Springwells.
Springwells Brick Co	1009 Hammond Bldg., Detroit	Springwells.
Wolf Brick Co., F. H	1467 Central Ave., Detroit	Detroit.
Pewabic Pottery & Tile Co	2161 Jefferson Ave., Detroit	Detroit.

SAND-LIME BRICK PRODUCERS, 1915.

Operators.	Office.	Works.
Genesee County:		
Flint Sandstone Brick Co	Flint	Flint.
Houghton County:		
Lake Superior Stone Brick Co	Calumet	Ripley.
Huron County:		
Sebewaing Sandstone Brick Co	Sebewaing	Sebewaing.
Jackson County:		
Jackson-Lansing Brick Co	Rives Junction	Rives Junction.
Kalamazoo County:		
South Michigan Brick Co	Kalamazoo	Kalamazoo.
Kent County:		
Grande Brick Co	Kalamazoo Ave., Grand Rapids	Grand Rapids.
Menominee County:		
Menominee Brick Co	Menominee	Menominee.
Oakland County:		
Rochester Brick & Sand Co	Rochester	Rochester.
Saginaw County:		
Saginaw Brick Co	321 N. Hamilton St., Saginaw	Saginaw.
Wayne County:		
Michigan Pressed Brick Co	Cor. Lawton Ave., and M. C. R. R., Detroit	Detroit.
Church Brick Co	Sibley	Sibley.
Fairview Brick Co	Foot of Jean St., Detroit	Detroit.

CEMENT PRODUCERS, 1915.

Operators.	Office.	Works.
Huron Portland Cement Co	1525 Ford Bldg., Detroit.	Alpena.
Burt Portland Cement Co	Bellevue	Bellevue.
Peninsular Portland Cement Co	Cooley Block, Jackson	Cement City.
Michigan Portland Cement Co	Chelsea	Four Mile Lake.
Wolverine Portland Cement Co	Coldwater	Coldwater and Quincy.
New Aetna Portland Cement Co	412 Union Trust Bldg., Detroit	Fenton.
Omega Portland Cement Co	Jonesville	Mosherville.
Newaygo Portland Cement Co	Grand Rapids	Newaygo.
Peerless Portland Cement Co	Union City	Union City.
Wyandotte Portland Cement Co	1525 Ford Bldg., Detroit.	Wyandotte.
Egyptian Portland Cement Co	Fenton	Fenton.

LIST OF MICHIGAN COAL MINES, LOCATION BY COUNTY, NAMES OF MANAGERS AND SUPERINTENDENTS.

Name of mine.	County.	Manager.	Address.	Superintendent.	Address.
Robert Gage Coal Co. No. 6	Bay	Chas. Coryell	Bay City	H. C. Lewis	Bay City.
Robert Gage Coal Co. No. 7	Bay	Chas. Coryell	Bay City	John Coryell	Bay City.
Beaver Coal Company	Bay	Chas. Coryell	Bay City	John Coryell	Bay City.
Wolverine Coal Mining Company No. 3	Bay	R. M. Randall	Saginaw	Alex Liddle	Bay City.
Wolverine Coal Mining Company No. 2	Bay	R. M. Randall	Saginaw	Alex Liddle	Bay City.
What Cheer Coal Mining Company No. 1	Bay	E. B. Foss	Bay City	Alex Jeffreys	Bay City.
Calhoun County Coal Co	Calhoun	Chas. Butler	Albion		
Eben Wright Mine	Eaton	Eben Wright	Grand Ledge	Eben Wright	Grand Ledge.
What Cheer Coal Mining Company No. 2	Genesee	E. B. Foss	Bay City	Alex Jeffreys	Bay City.
Cedar River Coal Mining Company	Ingham	Thos. M. Jenkins	Williamston	Thos. M. Jenkins	Williamston.
Robert Gage Coal Company No. 2	Saginaw	Chas. Coryell	Bay City	Richard Jenkins	St. Charles.
Bliss Coal Mining Company	Saginaw	John T. Phillips	Saginaw	John E. Evans	Saginaw. Swan Creek.
Banner Coal Mining Company	Saginaw	Wm. B. Carmichael	Saginaw Swan Creek	Jos. Skillcorn	Saginaw. Swan Creek.
Shiawassee Coal Mining Company	Saginaw	R. M. Randall	Saginaw	Thos. Westwood	Saginaw.
Pere Marquette Coal Company No. 3	Saginaw	R. M. Randall	Saginaw	R. Johnston	Saginaw.
Chappell and Fordney No. 2	Saginaw	R. M. Randall	Saginaw	Tim Hollis	Saginaw.
Caledonia Coal Mining Company No. 3	Saginaw	John Dagan	Saginaw	Geo. Theily	Saginaw.
Savage Coal Mining Company	Saginaw	Ed. Savage	Saginaw	Fred Johnston	Saginaw.
Wolverine Brick Co	Shiawassee	Wm. Brooks	Detroit		Corunna.
McAvoy Coal Co	Shiawassee	Wm. McAvoy	Owosso		
Akron Coal Mining Company	Tuscola	Chas. Handy	Bay City (W. S.)	John Morris	Akron.

Hon. Thomas Canary, State Coal Mine Inspector, Saginaw, Michigan.

CLAY MINERS, 1915.

Operators.	Office.	Mine.
Ontonagon County:		
Emmond, Wm. F	Rockland	Rockland.
Robinson Clay Products Co	1010 E. Market St., Akron, Ohio	Rockland.
Vogtlin, W. P	Rockland	Rockland.
Jeffs, F. A	Rockland	Rockland.
Jeffs Land Co., Ltd	Rockland	Rockland.
Wayne County:		
Geo. H. Clippert & Bro. Brick Co	Detroit	Springwells.
Wexford County:		
Stanley & Son, J. Z	Harriette	Harriette.

COKE PRODUCERS, 1915.

Operators.	Address.	Location of plant.	No. of ovens.	County.
Michigan Alkali Co	Wyandotte	Plant No. 2	30	Wayne.
Semet-Solvay Co	Syracuse, N. Y	Detroit	175	Wayne.

NATURAL GAS PRODUCERS, 1915.

Operator.	Address.
Benzie County:	
Gordon & Conklin	Beulah.
Hillsdale County:	
DeWitt, C. M	Osseo.
Macomb County:	
Hanekow, Mrs. Wm. H	Warren, R. F. D. No. 2.
Hartsig, Wm. L	Warren, R. F. D. No. 2.
Jacobs, Edward and Otto	Warren, R. F. D. No. 2.
Elwart, Franz	Warren, R. F. D. No. 2.
Oakland County:	
Landau, Ed	Royal Oak, R. D.
McClelland, James	Redford.
St. Clair County:	
Haas, H. G	Port Huron, 1615 Griswold St.
Michigan Central Oil, Gas and Mineral Co	Port Huron.
Michigan Development Co	Port Huron.
Stevens, H. Leroy	Port Huron.
Stock Co., G. B., Xylite Grease and Oil Co	Port Huron.
Mason, F. H	Port Huron, 2478 Military St.
Howe, Geo. W	Port Huron, 4008 Military St.
Lawrence, Gillett	Port Huron.
May, Henry	Port Huron.
Rowe, John A	Marysville.
Stevens, H. Leroy	Port Huron.
Washtenaw County:	
Harmon, H. E	Willis.
Wayne County:	
Becker, Irving	Redford.

GRAPHITE PRODUCERS, 1915.

Name.	Address.	Quarry.
Detroit Graphite Co.	10, 12th St., Detroit	L'Anse.
Northern Graphite Co.	L'Anse	L'Anse.

GRINDSTONE AND SCYTHESTONE PRODUCERS, 1915.

Operator.	Office.	Quarry.
Huron County:		
Cleveland Stone Co.	Cleveland, Ohio	Grindstone City.
The Wallace Co.	Port Austin	Eagle Mills.
Cleveland Stone Co.	Cleveland, Ohio	Port Austin.

PRODUCERS OF GYPSUM PRODUCTS, 1915.

Operator.	Office.	Name of plant.	Location of mine.
United States Gypsum Co.	Chicago, Ill.	Alabaster	Alabaster.
United States Gypsum Co.	Chicago, Ill.	Midland	Grand Rapids.
Acme Cement Plaster Co.	St. Louis, Mo.	Mill No. 5	Beverly.
Michigan Gypsum Co.	Grand Rapids		Grand Rapids.
American Cement Plaster Co.	Lawrence, Kas.	Grand Rapids	Grand Rapids.
Grand Rapids Plaster Co.	427 Mich. Trust Bldg., Gd. Rapids	Eagle Mill	Grand Rapids.
		Grandville	Grandville.

LIMESTONE AND LIME PRODUCERS, 1915.

Operators.	Office.	Quarry.
Alpena County:		
Collins, R. (also lime)	151 Water St., Alpena	Alpena.
Michigan Alkali Co	Wyandotte	Wyandotte.
Great Lakes Stone and Lime Co	Alpena	Rockport.
Arenac County:		
McDonnell, Jas. (lime)	Twining	Omer.
Charlevoix County:		
Northern Lime Co. (lime)	Petoskey	Bay Shore.
Charlevoix Rock Products Co. (also lime)	Charlevoix	Charlevoix.
Cheboygan County:		
Campbell Stone Co. (also lime)	Indian River	Afton.
Cheboygan Limestone Products Co	Mackinaw City	Mill Creek.
Delta County:		
Delta Contracting Co	Escanaba	Escanaba (Hyde).
Bichler Bros	Gladstone	Pine Ridge.
Bichler, John	Groos	Groos.
Dickinson County:		
Metronite Co., The	Milwaukee, Wis	Felch.
Emmet County:		
Antrim Lime Co. (lime)	912 Mich. Trust Bldg., Grand Rapids	Petoskey.
Northern Lime Co. (also lime)	Petoskey	Petoskey.
Petoskey Crushed Stone Co	Petoskey	Petoskey.
Mackinac County:		
Ozark Stone Quarry	Ozark	Ozark.
Union Carbide Co	42nd St. Bldg., New York, N. Y.	Hendricks Quarry.
Fiborn Limestone Co	Sault Ste. Marie, Ontario, Can	Fiborn Quarry.
Marquette County:		
City of Negaunee	Negaunee	Negaunee.
Menominee County:		
Menominee Stone Crusher	Menominee	Menominee.
Monroe County:		
Shore Line Stone Co	Monroe	Frenchtown.
The France Stone Co	1800 Second Nat'l Bank Bldg., Toledo, O	Monroe.
Chas. Angerer, Jr	Maybee	Scofield.
Presque Isle County:		
Michigan Limestone & Chemical Co	55 Liberty St., New York, or Rogers City, Mich	Calcite.
Schoolcraft County:		
The White Marble Lime Co	Manistique (Also lime)	Blaney, Manistique and Marblehead.
Delta Contracting Co	Escanaba	Manistique.
Wayne County:		
Solvay Process Co	Syracuse, N. Y	Trenton and Sibley.
Dunbar Stone Co	Detroit or River Rouge	Mouth of Detroit River.

MINERAL PAINT PRODUCERS, 1915.

Operator.	Pigment.	Office.	Location of plant.
Acme White Lead & Color Works	White lead, red lead, litharge, orange mineral	Detroit	Detroit.
Ditzler Color Co		Detroit	Detroit.
Metronite Co	Whiting (paint filler)	Milwaukee, Wis.	Dickinson Co.
Pickands, Mather & Co	Met. Paint	Cleveland, Ohio.	Iron county.

MINERAL AND SPRING WATER PRODUCERS, 1915.

Operators.	Office.	Spring.
Arctic Spring Water Co	412 Ottawa Ave., Grand Rapids	Arctic.
Bailey Marvel Springs Co	Bellaire	Alden.
Willis, J. L	Bangor	Beaver.
Bromo-Hygeia Mineral Water Co	Coldwater	Bromo-Hygeia.
Charlevoix Mineral Water Co	Charlevoix	Charlevoix.
Crystal Spring Water, Fuel & Ice Co	35 No. Division St., Grand Rapids	Crystal Spring.
Eastman Springs Co	Benton Harbor	Eastman.
Polaris Water Co	Marquette	Lake Superior Mineral Spring.
Mt. Clemens Crystal Springs Water Co.	Mt. Clemens	Mt. Clemens Crystal Spring.
Ogemaw Spring Water Co	Bay City	Ogemaw.
Dewitt, C. M	Osseo	Osseo.
Ponce de Leon Co	Grand Rapids	Ponce de Leon.
Pike, Lute H	Topinabee	Sanitas.
Shorkey, Chas	Mt. Clemens	Victory.
Ypsilanti Mineral Water & Bath Co	Ypsilanti	Moorman Well.
Magnetic Spring Water Co	Saginaw, W. S	Andrew's Magnetic Mineral.
Beard Hill Mineral Spring Co	105 E. Bancroft St., Toledo, Ohio	Avoca.
Charbeneau, Jno. H	Mt. Clemens	Maple Leaf Springs.
Preussel, Frank W	47 Crocker Ave., Mt. Clemens	Panacea.
Oliver Co	Pontiac	Welcome Island.
Wall, W. J	South Haven	Crystal.
Jackson, Roger	Crystal Falls	Sterling.
Sutton, Geo	Hartford	Sultana.
Silver Springs Water Co	Detroit	Northville.
Eureka Bottling Co	Mt. Clemens	Eureka.

PETROLEUM PRODUCERS, 1915.

Operators.	Address.
Michigan Central Oil & Mineral Co	807 Pine St., Port Huron.
Stock Xylite Grease & Oil Co., G. B	Port Huron.

PIG IRON PRODUCERS, 1915.

Operator.	Office.	Name of furnace.	Location of furnace.
Lake Superior Iron & Chemical Co	Detroit	Boyne City	Boyne City.
Lake Superior Iron & Chemical Co	Detroit	Chocolay	Chocolay.
Mitchell-Diggins Iron Co	Cadillac	Cadillac	Cadillac.
Detroit Furnace Co	1069 Jefferson Ave., Detroit	Detroit	Detroit.
Detroit Iron & Steel Co	149 Jefferson Ave., Detroit	A & B	Detroit.
East Jordan Furnace Co	East Jordan		East Jordan.
Cleveland Cliffs Iron Co	Cleveland, Ohio	Pioneer No. 1	Gladstone.
Antrim Iron Co	Antrim	Antrim	Antrim.
Pioneer Iron Co	Marquette	Carp River	Near Marquette.
Pioneer Iron Co	Marquette	Pioneer No. 2	Near Marquette.
Stephenson Charcoal Iron Co		Stephenson	Wells.
Charcoal Iron Co. of America	Detroit	Chocolay	Chocolay.
Charcoal Iron Co. of America	Detroit	Boyne City	Boyne City.
Charcoal Iron Co. of America	Detroit	Elk Rapids	Elk Rapids.
Charcoal Iron Co. of America	Detroit	Manistique	Manistique.
Charcoal Iron Co. of America	Detroit	Newberry	Newberry.
New Process Metal Co	Marquette		Marquette.

POTTERY PRODUCERS, 1915.

Operator.	Office.	Works.
Ionia County:		
Ionia Pottery Co	Ionia	Ionia.
Macomb County:		
Mt. Clemens Pottery Co	Mt. Clemens	Mt. Clemens.
Wayne County:		
Detroit Flower Pot Co	490 Howard St., Detroit	Detroit.
Jeffery-Dewitt Co	Detroit	Detroit.
Hupprich, Anton	2161 Michigan Ave., Detroit	Detroit.
Pewabic Pottery & Tile Co	2161 Jefferson St., Detroit	Detroit.

QUARTZ PRODUCERS, 1915.

Operator.	Office.	Mine.
Marquette County:		
Michigan Quartz Silica Co	Milwaukee, Wis	Ishpeming.

SALT PRODUCERS, 1915.

Operators.	Office.	Works.
Bay County:		
Hine Lumber Co	Sta. A., Bay City	W. Bay City.
Isabella County:		
Van Schaack & Sons, Peter	118 Lake St., Chicago, Ill	Mt. Pleasant.
Manistee County:		
Peters Salt & Lumber Co., R. G	East Lake	East Lake.
Filer & Sons, Vacuum Pan Salt Wks	Filer City	Filer City.
The Buckley & Douglass Lumber Co	381 River St., Manistee	Manistee.
Sands Salt & Lumber Co., Louis	Manistee	Manistee.
Mason County:		
Anchor Salt Co	Ludington	Ludington.
Stearns Salt & Lumber Co	Ludington	Ludington.
Midland County:		
The Dow Chemical Co	Midland	Midland.
Saginaw County:		
Mershon, Eddy, Parker & Co	Saginaw	Carrollton.
Bliss & Van Auken Lumber Co	Saginaw, W. S	Saginaw.
Eastman Flooring Co., S. L	Saginaw, W. S	Saginaw.
Estate of Edward Germain	Holland Ave. near Genesee St., Saginaw, E. S	Saginaw.
Saginaw Plate Glass Co	Saginaw, W. S	Saginaw W. S.
Saginaw Salt Co	430 Shearer Bldg., Bay City	St. Charles.
Strable Salt Co	Saginaw	Saginaw.
St. Clair County:		
Michigan Salt Works	Marine City	Marine City.
Morton Salt Co	717 Ry. Ex., Chicago, Ill	Port Huron.
Diamond Crystal Salt Co	St. Clair	Port Huron.
Marine City Salt Co	Marine City	Marine City.
Wayne County:		
Inland Delray Salt Co	Detroit	Delray.
Solvay Process Co	Detroit	Delray.
Detroit Rock Salt Co	Scranton, Pa	Detroit.
Mulkey Salt Co	610 Equity Bldg., Detroit	Oakwood.
Kay Salt Co	Charleston, W. Va	Ecorse.
Worcester Salt Co	168 Duane St., New York, N. Y	Ecorse.
Michigan Alkali Co	Wyandotte	Wyandotte.
Pennsylvania Salt Mfg. Co	115 Chestnut St., Philadelphia, Pa.	Wyandotte.

SANDSTONE PRODUCERS, 1915.

Operator.	Office.	Quarry.
Houghton County:		
Portage Entry Redstone Co	Jacobsville	Jacobsville.
Huron County:		
Cleveland Stone Co	Cleveland, Ohio	Grindstone.
Monroe County:		
Strouse, J. D	Ottawa Lake	Ottawa Lake.

SAND AND GRAVEL PRODUCERS, 1915.

Operator.	Office.	Pit.
Alcona County:		
Jas. Bell & Co	Greenbush	Greenbush.
Allegan County:		
Sutler, Fred W	Byron Center	Burnips Corners.
Wiest, Peter	Dorr, R. F. D. 2	Dorr.
Terpstra, Geo	Dunningville, R. F. D. 1	Dunningville.
Kool, Henry	New Richmond	New Richmond.
Pierce, Myron	Otsego	Otsego.
Powell, J. C	Plainwell	Plainwell.
Craine, W. C	Douglass	Douglass.
Hilaski, Stanley	Hopkins, R. F. D. 3	Hilliards.
Fry, W. G	South Haven, R. F. D. 6	South Haven.
Purdy, P	Fennville	Saugatuck.
Gray, Tom C	Fennville, R. F. D. 2	....
Dendel, M	Allegan, R. F. D. 5	Monterey.
Stuby, J. F	Moline	Wayland.
Alpena County:		
Riley & Monkman	501 State St., Alpena	Alpena.
Antrim County:		
Hilton, Robert	Bellaire, R. F. D. 1	Bellaire.
Sissons, F. E	Central Lake, R. F. D. 1	Central Lake.
McPherson, Guy	Eastport	Eastport.
Campbell, W	Mancelona	Mancelona.
Swan, Guy	Mancelona	Mancelona.
Burch, A. O	Central Lake	Central Lake.
Arenac County:		
Wells, A. H	Standish, R. F. D. 2	Standish.
Daniels, Wm	Sterling, R. F. D	Sterling.
Rogers, Sidney	Twining	Twining.
Mayor of Omer City	Omer	Omer.
Barry County:		
Woolston, Chas	Hastings	Hastings.
Hitt, Geo	Woodland	Woodland.
Renkes, Fred	Hastings	Hastings.
Dunham, P. O	Nashville	Grove Center.
Clever, Daniel	Nashville	Nashville.
Hinckley, C. G	Hastings	Hastings.
Bay County:		
Hayward, R	Bay City, R. F. D. 3	Bay City.
Histed, C. D	Munger	Munger.
Whitney, Geo. A	Bentley	Bentley.
Benzie County:		
Huddleston, Wm	Bendon, R. F. D. 1	Bendon.
Betsey River Orchards, Ben Newhall & Co	840 Ohio Bldg., Chicago, or Thompsonville, Mich	Thompsonville.
Berrien County:		
Edgecombe, Geo. W	439 Main St., Benton Harbor	Benton Harbor.
Warren, Paul E	Lakeside	Lakeside.
Benton Harbor Sand Co	Benton Harbor	Benton Harbor.
American Sand & Gravel Co	Benton Harbor	Benton Harbor.
Garden City Sand Co	Riverside	Riverside.
Kerlikowske Bros	St. Joseph	St. Joseph.
Brown, H. C	Berrien Springs	Baroda.
Brewer, Frank	Galien	Galien.
Thar, Anton	Coloma, R. F. D. 3	Riverside.
Broderick Bros	Riverside	Riverside.
Brant, Mrs. Rebecca	Bridgeman	Bridgeman.
Swank, Wm	Galien	Galien.
Mettger, Henry	Berrien Springs	Oronoka.
Branch County:		
Werner, Jake F	Bronson	Bronson.
Barnes, Mrs. J. M	Montgomery	Kinderhook.
Brehm, Jno. H	Kinderhook	Kinderhook.
Clark, Oliver	Kinderhook, R. F. D. 1	Kinderhook.
Wilkins, W. H	Coldwater, R. F. D. 3	Kinderhook.

SAND AND GRAVEL PRODUCERS, 1915.—*Continued.*

Operator.	Office.	Pit.
Calhoun County:		
March, Andrew	Union City, R. F. D. 5	Union City.
Young, Willard A	Albion	Albion.
Blowers, N. A	Athens	Athens.
Funk, F. J	Battle Creek, R. F. D. 2	Battle Creek.
Hiscock, Seth	Battle Creek	Battle Creek.
Grosbeck, Fred	Burlington	Burlington.
Adrian, John	323 Hamblin Ave	Battle Creek.
Crystal Sand & Gravel Co	12 E. Main St., Battle Creek	Battle Creek.
Brownlee Park & Material Co	Battle Creek	Brownlee Park.
Michigan United Traction Co	Jackson	Marshall.
Prince, Wm. A	Ceresco	Ceresco.
Phillips, L. W	Burlington	Burlington.
Van Sickles, Elmer	Albion	Albion.
Cass County:		
La Grange Twp	Cassopolis	Cassopolis.
Crandall, Lester	Cassopolis	Cassopolis.
Blanchard, A. G	Niles	Niles.
Graham, H. A	Elkhart, Ind	Union.
Charlevoix County:		
Healy, Chas	East Jordan, R. F. D. 2	East Jordan.
Cheboygan County:		
Charpointiar, Jos	Cheboygan, R. F. D. 2	Cheboygan.
Chippewa County:		
Belanger, Louis	Sault Ste. Marie	Sault Ste. Marie.
Rye, Jas	409 Maple St., Sault Ste. Marie	Sault Ste. Marie.
Clare County:		
Littlefield, J. L	Farwell	Farwell.
Clinton County:		
Parmenter, Geo	Shepardsville	Shepardsville.
Gleason, S. B	Ovid	Ovid.
Allen, Frank	Elsie	Elsie.
Keys, Hiram	St. Johns	St. Johns.
Wilhelm, Noah	Bath, R. D	Bath.
Mich. United Traction Co	Jackson	DeWitt.
Stowell, Elmer	Ovid	Ovid.
Coats, Lewey	Ovid	Ovid.
Crawford County:		
Latham, Nathan J	Grayling	Grayling.
Delta County:		
Potvin, Louis	Garden	Garden.
Chicago & N. W. R. R	Chicago	Escanaba.
Escanaba Stone & Gravel Co	Escanaba	Escanaba, Flat Rock.
Jorgensen, Adolph	Escanaba	Escanaba.
Bereman, Andrew	Gladstone	Gladstone.
Dickinson County:		
Chicago & N. W. R. R	Chicago	Iron Mountain and Loretto.
Vulcan Brick Works	Vulcan	Vulcan.
Eaton County:		
Palmiter, S. J	Bellevue, R. F. D. 4	Bellevue.
Hull Bros	Dimondale	Dimondale.
Johnson, A. C	Eaton Rapids	Eaton Rapids.
LaRock, Hiram	Grand Ledge	Grand Ledge.
Gates, Burton	Grand Ledge	Grand Ledge.
Kent, V. M	Grand Ledge	Grand Ledge.
Saier, H. E	Lansing, R. F. D. 6	Millett.
Wells, C. E	Vermontville	Vermontville.
Genesee County:		
Bird, Jos	Davison	Davison.
Burns, Ed	Duffield	Duffield.
Farnham, Henry	Farnham, R. F. D. 3	Fenton.
Flint Sandstone Brick Co	Flint	Flint.
Reid, Alfred	Flint	Flint.
Scott, F. D	Genesee	Genesee.
Boston, H. W	Goodrich, R. F. D. 1	Goodrich.

SAND AND GRAVEL PRODUCERS, 1915.—*Continued.*

Operator.	Office.	Pit.
Genesee County:—Con.		
Stine, Martin	Goodrich	Goodrich.
Bowles, E	Linden	Linden.
Hogan, Daniel	Linden	Linden.
Brown, D	Duffield	Duffield.
Johnson, Ernie	Swartz Creek	Swartz Creek.
Knox, Wm	Linden	Argentine.
Goodrich, Wm. P	Goodrich	Goodrich.
Bigelow, Edna H	Grand Blanc	Grand Blanc.
Grand Traverse County:		
Koch, John	Mayfield	Mayfield.
Gratiot County:		
Church, J. H	Alma	Alma.
Sawvel, Robert	Breckenridge	Breckenridge.
Lippert, Jacob	Elwell	Elwell.
Curtis, C	Ithaca, R. F. D. 6	Ithaca.
Haas Bros	Northstar, R. F. D. 3	Northstar.
Tomlin, A	Sumner	Sumner.
Wiles, Wm	Sumner, R. F. D. 2	Sumner.
Hillsdale County:		
Crowl, A	Camden	Camden.
Morgan, H. C	Camden, R. F. D. 37	Camden.
Sholfield, H. C	Pittsford	Pittsford.
Thompson, L. W	Waldron	Waldron.
Wolcott, C. Nelson E	Hillsdale	Hillsdale.
Kline, H. N	Camden	Camden.
Houghton County:		
Winona Copper Co	Winona	Winona.
Huron County:		
Conkey, Sam	Caseville	Caseville.
Merrick Gravel Co	Pigeon	Pigeon.
Wallace Co., The	Port Austin	Port Austin.
Haskell, Miss Eliz. A	Port Austin	Port Austin.
Ingham County:		
Artz, Joe	Leslie	Sec. 23, Bunker Hill Twp.
Atkinson, Mr	Mason	S. W. Cor. Sec. 16, Vevay Twp.
Bell, O. E	Mason or Lansing	Sec. 36, Delhi Twp.
Bunker, Chas	Leslie or Stockbridge	Sec. 35, Bunker Hill Twp.
Corwin, W. L	Williamston	Sec. 2, Wheatfield Twp.
Couch, Chas	Mason	Sec. 25, Aurelius Twp.
Curtiss, Bert	Williamston	N. E. Cor. Sec. 21, Wheatfield Twp.
Potts, W. S	Mason, R. F. D. 1	Mason.
Dubois, D. D	Leslie	Sec. 28, Bunker Hill Twp.
Frost, A. J	Williamston	Sec. 22, Wheatfield Twp.
Frost, J. F	Williamston	Sec. 26, Wheatfield Twp.
Holbrook & Skinner	Lansing	Lansing (Holt).
Linn, Lew	Williamston	Sec. 15, Wheatfield Twp.
Saler, H. E	Lansing, R. F. D. 6	Lansing.
Stockman, F. M	Lansing	Lansing.
Shortwell, E. F	Leslie (or Stockbridge)	Sec. 35, Bunker Hill Twp.
Campbell, Hugh	1516 6th St., Bay City	Mason.
Nice, Geo	Mason	Sec. 6, Vevay Twp.
Okobock, Dennis	Mason	Sec. 5, Vevay Twp.
Potts, Walter F	Mason, R. F. D. 1	Mason.
Rappe, A	Lansing or E. Lansing	Sec. 16, Meridian Twp.
Porter	Williamston	Sec. 34, Williamston Twp.
Sheltraw, A. E	Saginaw	Mason.
Smith, Geo	Mason	Sec. 10, Vevay Twp.
Stevens, F. B	Mason	Sec. 5, Vevay Twp.
Victory, Ward	Leslie or Stockbridge	Sec. 36, Bunker Hill Twp.
Michigan United Traction Co	Jackson	Sec. 25, Delhi Twp., Mason and Haslett.
Warner, Mr	Mason	N. W. Cor. Sec. 36, Aurelius Twp.
Williams, C. W	Williamston	Sec. 35, Williamston Twp.
Winters, J. P	Leslie or Stockbridge	Sec. 25, Bunker Hill Twp.
Graves, Frank	Williamston	Williamston.

SAND AND GRAVEL PRODUCERS, 1915.—*Continued.*

Operator.	Office.	Pit.
Ionia County:		
Crawford, Geo. W	Ionia, R. F. D. 3	Ionia.
Ionia Cement Products Co	Ionia	Ionia.
Miller, Henry	East Main St., Ionia	Ionia.
Normington, Frank	Ionia, R. F. D. 1	Ionia.
Knapp, A. M	Ionia, R. F. D. 7	Ionia.
Trowbridge, Forest P	Ionia	Ionia.
Soper, Frank	Ionia	Muir.
Hazelitt, J. I	Ionia, Star Route	Palo.
Dansinger, Samuel	Saranac, R. F. D. 1	Saranac.
Gillmore, Niel	Shiloh	Shiloh.
Fellows, Jas. M	Lake Odessa	Lake Odessa.
Hauserman, Herman	Lake Odessa, R. F. D	Lake Odessa.
Millard, Seymour	Palo	Palo.
Ronald Twp. Gravel Pit	Palo	Palo.
Grieves, Mrs	Saranac, R. F. D. 12	Saranac.
Keyser, Chas	Saranac, R. F. D. 10	Saranac.
Iosco County:		
Boomer & Son, Jno	Tawas City	Tawas City.
Iron County:		
Kimball, Ray	Crystal Falls	Crystal Falls.
Chicago, Milwaukee & St. Paul R. R	Chicago	Crystal Falls.
Isabella County:		
Winans, Frank	Blanchard	Blanchard.
Coughlin, Will	Shepherd, R. F. D. 1	Shepherd.
Dexter, James	Shepherd	Shepherd.
Jackson County:		
Greenville Gravel Co	Greenville	Ackerman Lake.
Cooper, Fred	Horton	Horton.
Winters, J. P	Jackson	Jackson.
Blackmarr, Chas	107 Stewart Ave., Jackson	Jackson.
Blake, Wm	Jackson, R. F. D. 6	Jackson.
Emmons, Wm. P	123 Clinton St., Jackson	Jackson.
Meyers, Albert	Jackson, R. F. D. 6	Jackson.
Watts, C. R	Jackson, R. F. D. 2	Jackson.
Berm, C. E	Parma	Parma.
Mich. Central R. R. Co	Detroit	Bloomerville.
Mich. United Traction Co	Jackson	Michigan City.
Hunn, G. L	Parma	Parma.
The Greenville Gravel Co	Greenville, O	Ackerman Lake, 3 miles S. of Jackson.
Kalamazoo County:		
Mich. United Traction Co	Jackson	Augusta.
Miller, J. B	Augusta	Augusta.
Balch, Wm. A	Kalamazoo	Kalamazoo.
Balch, Uriel K	Kalamazoo	Kalamazoo.
Buurma, Sam'l H	Kalamazoo	Kalamazoo.
Haas Bros	Kalamazoo	Kalamazoo.
Huff, Archie	Kalamazoo	Kalamazoo.
Klepper, Jacob	Kalamazoo	Kalamazoo.
Molhock, Peter	Kalamazoo	Kalamazoo.
Owens, Michael	Kalamazoo	Kalamazoo.
Russell, Jas. T	Kalamazoo	Kalamazoo.
So. Mich. Brick Co	Kalamazoo	Richland Twp.
Mich. United Traction Co	Jackson	Augusta.
Mich. Railway Engineering Co	Kalamazoo	Richland.
Gunn, J. W	Watervliet	Williams.
Kalkaska County:		
Anderson, Lind	Kalkaska	Kalkaska.
Hayward, W. F	South Boardman	South Boardman.
Kent County:		
Holt, C. E	Ada, R. F. D. 42	Ada.
Deiss, Jos	Ada, R. F. D. 17	Alpine.
Reed, Percy	Alpine	Alpine.
Brewer, Earl	Byron Center, R. F. D	Byron Center.
Battjes Fuel & Bldg. Mat. Co	Grand Rapids	Grand Rapids.
Bunker Co., G. W	Grand Rapids	Grand Rapids.
Harrison Land Co., Ltd	Grand Rapids	Grand Rapids.
Carpenter Construction Co	Grand Rapids	Grand Rapids.
Pinyon, S. G	Grand Rapids	Grand Rapids.
Valley City Stone & Gravel Co	Grand Rapids	Grand Rapids.

SAND AND GRAVEL PRODUCERS, 1915.—*Continued.*

Operator.	Office.	Pit.
Kent County.—Con.		
Ide, D. K.	Grandville	Grandville.
Maloney, Pat	Harvard, R. F. D. 40	Harvard.
Holmgren, E. A.	Kent City	Kent City.
Kriger, M.	Kent City	Kent City.
Ryno, M. J.	Ross, R. F. D.	Ross.
Farnam, Reuben	Sand Lake	Sand Lake.
Standard Builders Supply Co.	Grand Rapids	Grand Rapids.
Kloote Sand and Gravel Co.	Grand Rapids	Grand Rapids.
Lake County:		
Saunders & Co., G. W.	Chase	Chase.
Lapeer County:		
Hallock, Roy P.	Almont	Almont.
Miteen, Fred	Goodrich	Goodrich.
Caley, M.	Metamora	Hunters Creek.
Leelanau County:		
Bronson, Margaret	Maple City, R. F. D. 1	Maple City.
Lenawee County:		
Shannon, F. J.	Adrian	Adrian.
Smith, Porter C.	Clinton	Clinton.
Fuller, Charles	Hudson	Hudson.
Lockwood, Sam	Hudson	Hudson.
Lowe, Frank	Hudson	Hudson.
Evans, Geo.	N. Morenci	N. Morenci.
Gillispie, R. P.	Tecumseh	Tecumseh.
Wilson, Ira	Tecumseh, R. F. D. 3	Tecumseh.
Tecumseh Gravel Co.	Tecumseh	Tecumseh.
Livingston County:		
Ohio & Michigan Sand & Gravel Co.	1025 Nicholas Bldg., Toledo, Ohio	Chilson.
Coles, Ben	Fowlerville	Fowlerville.
Arnold, O. B.	Gregory	Gregory.
Butler, Dwight	Hamburg	Hamburg.
Hosby, E. B.	Howell	Howell.
Thomas, Henry	Oak Grove	Oak Grove.
Macomb County:		
Horning Gravel Co.	412 Weadock Bldg., Saginaw	Armada.
Pratt, Ben J.	Armada	Armada.
Chapman, Jas.	Memphis	Memphis.
Lake Side Ice & Coal Co.	Mt. Clemens	Mt. Clemens.
Harder, Henry	Richmond	Richmond.
Wacker, H. Jacob	Mt. Clemens	Mt. Clemens.
Savedore, Jos.	Utica, R. F. D. 2	Utica.
Detroit Sand & Gravel Co.	34 McGraw Bldg., Detroit	Utica.
Superior Sand & Gravel Co.	Detroit	Utica.
Manistee County:		
Hansen, Chris	Manistee	Manistee.
Hubbell Sand Co.	Manistee	Manistee.
Miller Bros. & Co.	Manistee	Manistee.
Summerfield, Porter M.	Manistee	Manistee.
Farr, M. A.	Onekama	Onekama.
McMartin, Chas.	Chief, R. F. D. 2	Chief.
Johnson, John	Chief	Chief.
Marquette County:		
Chicago & N. W. R. R.	Chicago	Michigamme.
Mason County:		
Hail, Ed.	Custer, R. F. D. 2	Custer.
Szymanski, Geo.	Freesoil, R. F. D. 2	Freesoil.
Wahr, John	Freesoil, R. F. D. 2	Freesoil.
Beaune, Oliver	Ludington, Box 68	Ludington.
Clark, Henry	Ludington	Ludington.
Lorentz, Ferdinand	Ludington	Ludington.
Dodge, C. C.	Tallman	Tallman.
Edmonson, James	Tallman	Tallman.
Herman, Rosman	Freesoil	....
Percy, Stanton	Ludington	Ludington.

SAND AND GRAVEL PRODUCERS, 1915.—*Continued.*

Operator.	Office.	Pit.
Mecosta County:		
Conklin, Wm	Big Rapids, R. F. D. 5	Big Rapids.
Riley, J. E	Millbrook, R. F. D. 2	Millbrook.
Midland County:		
Troyer, D. J	Brier	Brier.
Gehoski, Mike	Midland, R. F. D. 1	Midland.
Missaukee County:		
Pickering, O. L	Lake City	Lake City.
Reeves, Kary D	McLean, Ill	McBain.
Monroe County:		
Falmstock, Emerson	Carlton	Carlton.
Stoeckert, Wm	Monroe	Monroe.
National Silica Co	Steiner	Steiner.
Montcalm County:		
Belknap Cement Products Co	Greenville	Greenville.
Boerwinkle, Wm	Pierson	Pierson.
Matz, Chas	Pierson	Pierson.
Tissue, Lenn	Stanton, R. F. D. 1	Stanton.
Sinkey, Mrs. L. M	Carson City	Carson City.
Larsen, Geo	Greenville, R. F. D. 3	Greenville.
Williams, E. O	Edmore	Edmore.
Muskegon County:		
Bettis, Phil	Ravenna, R. F. D	Ravenna.
Homer, Wm	Ravenna, R. F. D	Ravenna.
Valley, Edw	Twin Lakes	Twin Lakes.
Newaygo County:		
Wentland, Mrs. Johanna	Woodville	Woodville.
Hall, A. E	Newaygo	Newaygo.
Nieboer, J	Grant	Grant.
Raymond, R. J	Grant	Grant.
Oakland County:		
Park & Son, A. H	Birmingham, R. F. D. 2	Birmingham.
Mich. Portland Cement Paving Co	Griswold St., Detroit	Clarkston.
Ely, C	Farmington	Farmington.
Rice, E. J	New Hudson	New Hudson.
Campbell, John	Ortonville, R. F. D. 2	Ortonville.
Detroit-Oxford Gravel & Stone Co	Oxford	Oxford.
Bartlett, C. S. & A. S	Pontiac	Pontiac, 2 miles E.
Kemp, W. H	Pontiac	Pontiac.
Rockwell, C. L	Pontiac	Pontiac.
Slater Construction Co	Pontiac	Pontiac.
Heal, Geo	669 Baker St., Detroit	Rochester.
Rochester Sand & Brick Co	Detroit	Rochester.
Boomer Sand & Gravel Co	520 Forest St. E., Detroit	Rochester.
Packham, H. H	1715 Dime Bk. Bldg., Detroit	Goodison.
Adams & Cummings	1105 Kresge Bldg., Detroit	New Hudson.
Oceana County:		
Aldrich, A. O	Hart	Crystal Valley.
Golden Twp. Pit	Mears	Mears.
Twp. Board of Newfield	Hesperia	Hesperia.
Cartright, Thos	Rothbury, R. F. D. 1	Rothbury.
Wherle, Frank	Rothbury, R. F. D. 1	Rothbury.
Ogemaw County:		
Brooks, H. F	Rose City	Rose City.
Harvey, D	West Branch, R. F. D. 1	West Branch.
Osceola County:		
Carmichael, Ed	Evart, R. F. D. 1	Evart.
White & Day	Evart	Evart.
Stone, Chas. E	Hersey, R. F. D. 1	Hersey.
Hoogerhide, Jno	Reed City, R. F. D. 6	Reed City.
Marvin, Seymour	Tustin, R. F. D. 1	Tustin.

SAND AND GRAVEL PRODUCERS, 1915.—*Continued.*

Operator.	Office.	Pit.
Ottawa County:		
Holthrop, Jno	Ferrysburg	Ferrysburg.
Graham, Mrs. T	Grand Haven	Grand Haven.
Walsma Van Toll Co	Grand Haven	Bass River.
Van Weelden & Co., J	609 Fulton St., Grand Haven	Grand Haven.
Presque Isle County:		
Kroll, Andrew	Posen	Posen.
Roscommon County:		
Campbell Gravel Co	Roscommon	Roscommon.
St. Clair County:		
Armitage, Sidney	Atkins, R. F. D. 1	Atkins.
Kinney, Chester	Atkins, R. F. D. 1	Atkins.
Snyder, Wm	Atkins, R. F. D. 1	Atkins.
Kitchen, Cyrenius	Smiths Creek	Goodells.
McGennett, Jas	Smiths Creek	Smiths Creek.
Westrick & Son, C. A	Marine City	Marine City.
Caldwell Transit Co	1805 Dime Bk. Bldg., Detroit	St. Clair River and Lake.
Jacques & Sons, E	Foot of 1st St., Duluth, Minn	Port Huron.
Marine Contracting Co	211 Quay St., Port Huron	Port Huron.
St. Joseph County:		
Hill, S	Colon	Colon.
Wade, H. H	White Pigeon	White Pigeon.
Kerlikowske Bros	St. Joseph	St. Joseph.
Sanilac County:		
McKillen, David	Brown City	Brown City.
Swaffer, Chas	Deckerville	Deckerville.
Buck, C. J	Marlette	Marlette.
Gilbert, Geo	Melvin, R. F. D. 6	Melvin.
Mills, Henry	Minden City	Minden City.
Dawson & Son	Sandusky	Sandusky.
Shiawassee County:		
Graham, John	Byron	Byron.
Shannon, A. E	Byron	Byron.
Schultz, A. A	Laingsburg	Laingsburg.
Hibbard, Joseph	Byron	Byron.
Tuscola County:		
Hill, Tom	Caro	Caro.
Baker, Gilbert	Kingston	Kingston.
Whittaker, Benson	Kingston	Kingston.
Donigan, Joseph	Millington	Millington.
Hill, Elmer A	Unionville	Silverwood.
Van Buren County:		
Burger, F. A	Bangor	Bangor.
Hoppin, A. D	Bangor	Bangor.
Shine, John	Bangor	Bangor.
McKee, Jr., Darwin	Decatur	Decatur.
Orr, James	Decatur	Decatur.
Sherburn, John	Decatur	Decatur.
Otis, L. L	Kibbie	Kibbie.
Wright, J. E	Lawrence	Lawrence.
Fry, W. G	South Haven	South Haven.
Washtenaw County:		
City Concrete & Coal Co	1015 Dime Bank Bldg., Detroit	Delhi.
Eddie, Geo	Ann Arbor, R. F. D. 8	Ann Arbor.
Fiegel, Fred	Ann Arbor, R. F. D. 3	Ann Arbor.
Pease, Wm	Saline, R. F. D	Saline.
Youngs, Ed	Saline, R. F. D	Saline.
Crane, Mortimer R	217 Mich. St., Ypsilanti	Ypsilanti.
Elsifor, S. A	117 First St., Ann Arbor	Ann Arbor.
Washed Clean Sand & Gravel Co	Ann Arbor	Dexter.

SAND AND GRAVEL PRODUCERS, 1915.—*Concluded.*

Operator.	Office.	Pit.
Wayne County:		
Detroit United Fuel & Supply Co.	Detroit, Free Press Bldg.	Utica and Detroit.
Wabash R. R. Co., American Silica Co.	Rockwood.	Rockwood.
Thompson, W. R.	Detroit, 606 Kress Bldg.	Detroit.
Pryor, R. C.	Detroit, 933 Dime Bank Bldg.	1¼ miles E. of Rockwood.
Wexford County:		
Selma Twp. Pit	Cadillac	Boon.
Fewless, John	Manton, R. F. D. 3	Manton.

TRAP ROCK PRODUCERS, 1915.

Operator.	Office.	Quarry.
Marquette County:		
Durocher, T. L.	Marquette	Marquette.
The Park Cemetery Stone Co.	Marquette	Marquette.
City of Negaunee	Negaunee	Negaunee.
Marquette Trap Rock Co.	Marquette	Marquette.
Houghton County:		
Winona Copper Co.	Winona	Winona.

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